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Treasure Valley Water Distribution System: A Plan for Future Growth

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**Treasure Valley Water Distribution:
A Plan for Future Growth**

A Major Qualifying Project
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for the
degree of Bachelor of Science

by
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Adam Carrier
Bryan Sadowski

Date:
1 March 2016

Submitted to:

Professors Suzanne LePage and Paul Mathisen
Worcester Polytechnic Institute

This report represents work of WPI undergraduate students submitted to the faculty as evidence of a degree requirement. WPI routinely publishes these reports on its web site without editorial or peer review. For more information about the projects program at WPI, see <http://www.wpi.edu/Academics/Projects>

Abstract

This project explored options for Treasure Valley Scout Reservation (TVSR) to develop a compliant and fully operational water distribution system, while establishing a basis for expansion. The existing water network was detailed using GIS and assessed in relation to current and future needs. A number of alternatives were developed and cost estimates were provided to assist stakeholders in prioritizing camp improvements. Recommendations and alternatives were presented in order of feasibility to TVSR as a guide for the future.

Acknowledgements

The project team would like to thank the stakeholders of TVSR for their suggestions and assistance throughout the course of this project. Special acknowledgements for Tom Chamberland, Mike McQuaid, Ranger Matt, and Warren Balch for taking an active role by lending their experience and expertise. The team would also like to thank the advisors, Professor LePage and Professor Mathisen, for their guidance and constant support. Thanks to the Department of Conservation and Recreation for letting the team use their equipment, the librarians of WPI for their help during the early phases, and WPI for providing the opportunity to work on such an intriguing and versatile project.

Capstone Design Statement

Civil and Environmental Engineering

This project fulfills the capstone design requirement for the Bachelor of Science degree in the areas of Civil and Environmental Engineering at Worcester Polytechnic Institute. The requirements for capstone design are set by the Accreditation Board for Engineering and Technology (ABET) to give students an engineering design scenario where realistic constraints must be accounted for. The design experience must address constraints including economic, environmental, sustainability, constructability, ethical, health and safety, social, and political concerns. This project analyzes and designs alternative water distribution system modifications for Treasure Valley Scout Reservation. The design constraints included in this project are specified in the following paragraphs.

Economic

The final recommendations of the project take into account the cost of construction of each component. Recommendations for Treasure Valley include capital costs, labor costs, and unit costs for materials to improve the water system. Each component recommended was determined based on maximizing efficiency while minimizing the cost of implementation.

Environmental

Treasure Valley provides an opportunity to experience nature. Suggestions to improve the system are intended to have minimal impact on the surrounding ecosystem. All recommendations comply with state and federal regulations involving wetland and watershed protection.

Sustainability

This project attempted to ensure the long term sustainability of Treasure Valley by increasing the number of people the water system can service. The end result is a readily accessible resource that supports the maintenance and future expansion of Treasure Valley.

Constructability

The recommendations created for Treasure Valley are given in short term and long term improvements. The goal being that Treasure Valley can make improvements immediately while at the same time take steps in specified time intervals to make long term improvements related to the construction of new wells.

Ethical

Throughout the project, the project team followed ethical guidelines by presenting all gathered data honestly and provided recommendations that would be in the best interest of the reservation and its trustees. These ethical guidelines are set forth by the American Society of Civil Engineers.

Health and Safety

Since the project involved the distribution of drinking water, health regulation was a primary concern. The camp follows the Commonwealth of Massachusetts's health code as administered by the Town of Oakham's Board of Health for the regulation of TVSR's facilities. The project followed the state and federal regulations that govern the quality of public drinking water, such as

the Clean Water Drinking Act. All accessible drinking water was determined safe according to U.S. Environmental Protection Agency standards.

Social

With access to drinking water in more locations and improving the efficiency of the system, the capacity of the camp will be increased to house more users. The increased capacity of the system, along with long term recommendations, ensures the camp will have room for future growth.

Political

Treasure Valley spans four different towns each with their own set of regulations. Each addition to the water system follows the code of the town that part of the system lies in, and also must comply with all applicable state and federal regulations.

Professional Licensure

The purpose of professional licensure is to restrict practice to qualified individuals that have met specific qualifications. This process is regulated through the National Council of Examiners for Engineering and Surveying (NCEES) and is specific to each state within the United States. Each state has a state licensing board who regulates the laws by which licensure is governed, but there are general outlined steps put in place by the NCEES.

- Receive a degree of bachelors or higher from an ABET- accredited engineering program.
- Complete the FE exam.
- Attain work experience of four or more years under the guidance of a P.E.
- Pass the PE exam in the appropriate field.

Becoming a professional engineer or P.E. grants many privileges and responsibilities to the respective engineer. This is important because projects certified by a P.E. are held to a high ethical and engineering standard and indicate that the math and engineering is correct. A P.E. is able to offer services to the public, work for consulting firms, bid for contracts, and most importantly stamp and seal work plans and designs.

Massachusetts has outlined its own main steps in the application process that dictates the registration procedure. Registration occurs only after the following are satisfied:

- (I) meeting all the requirements of law;
- (II) passing the required examinations;
- (III) receiving notification from the Board; and
- (IV) paying the registration fee.

In regards to the project team's professional future, Massachusetts presented data in a table found in 250 CMR 3.00. This table outlines the educational requirements, necessary examinations, and references applicable to professional engineering practices in Massachusetts.

250 CMR 3.04(4): Table I Engineering Application Requirements					
Education Requirements	Engineering Experience	FE Exam	PE Exam	Interview	Reference
A Bachelor of Science degree in engineering from an ABET accredited program.	4 years	Yes	Yes	No	M.G.L.c. 112, § 81J (1)(b)

Tasks completed in our MQP were carried out in ways similar to that of professional engineers. The problems our team faced were similar to that for which an entry level engineer or a P.E. would encounter in their profession. Our team conducted field visits, worked with clients, completed calculations based on water delivery and demand, encountered obstacles, and worked consistently throughout to develop a recommendation worthy of our own "professional" seal. Some of the engineering challenges we overcame had real world considerations; such as regulations, monetary cost, feasibility, and safety. In this project, it is understood that our decisions, if implemented, will have a direct and important effect on the future of the client.

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Glossary of Terms

ArcGIS: Geo-referencing program used to analyze locations by utilizing multiple layers of data. Essential to the analysis and recommendations generated by this report as ArcGIS was the primary mapping program used by the project team.

Interim Wellhead Protection Area (IWPA): the interim wellhead protection area is applied to public water systems by DEP for wells or well fields that lack an approved Zone II radius. The IWPA is proportional to the approved pumping rate, as calculated by the following equation (310 CMR 22.02, 2009):

$$\text{IWPA radius in feet} = (32 \times \text{pumping rate in gallons per minute}) + 400$$

MassDEP: The Department of Environmental Protection is the state agency responsible for ensuring clean air and water, the safe management of toxics and hazards, the recycling of solid and hazardous wastes, the timely cleanup of hazardous waste sites and spills, and the preservation of wetlands and coastal resources (MassDEP, 2016a).

Polyvinyl chloride (PVC): Basic piping material used in plumbing systems around the world.

QGIS: Open source, internet based, geo-referencing program used to map data similar to ArcGIS. Utilized in this report as personal computers were not capable of running ArcGIS.

Transient Non-Community Water System: A public water system that has at least 15 service connections or serves water to 25 different persons at least 60 days of the year (310 CMR 22.02, 2009). This is the classification of Treasure Valley Scout Reservation used by the Commonwealth of Massachusetts.

Treasure Valley Scout Reservation (TVSR): The sponsor of this MQP. A Boy Scout reservation located in the central Massachusetts towns of Rutland, Oakham, Spencer, and Paxton.

Zone I Radius: the protective radius required around a public water supply well or well field by the DEP. The radius is determined using the following equation, and cannot be less than 100 feet (310 CMR 22.02, 2009):

$$\text{Zone I radius in feet} = (150 \times \log \text{ of pumping rate in gpd}) - 350$$

Zone II Radius: refers to the area of an aquifer that contributes water to a well under the most severe pumping and recharge conditions that can be anticipated. The area for Zone II radii is bounded by the groundwater divides that result from pumping the well and by the contact of the aquifer with less permeable materials. The radius must include the entire Zone I area.

1.0 Introduction

Treasure Valley Scout Reservation (TVSR) is a Boy Scout Reservation located in the towns of Rutland, Paxton, Oakham, and Spencer and serves Boy Scouts in Central Massachusetts. The Reservation provides a location for the Boy Scouts of America to learn valuable survival skills and enjoy the wilderness. This site is able to acquire and distribute its own drinking water to users of the camp through a water distribution system with groundwater wells and pipes. Currently, Treasure Valley's water system consists of three operational wells and one inactive well, servicing key areas of the Reservation with seasonal and year round water access. The system has an underground pipe network established for portions of the camp, and uses above ground piping to accommodate the many campsites.

However, TVSR is concerned about the ability of its water distribution system to support current and future demands of the Reservation. The Reservation is under the stewardship of a Trust that relies solely on grants and donations to maintain the facility. Because of their status as a Trust, financial costs are an important consideration in the development of potential solutions to ensure sustainability of for their water system (Mohegan Council, 2015). Throughout the years, the camp has grown in size and the number of campers attending its summer program has steadily increased. TVSR has been able to supply potable water throughout its history, but has recently reached an impasse in relation to water demands. For TVSR to ensure that its water system can meet current and future demand, as well as all current potable water regulations set by the Massachusetts Department of Environmental Protection (MassDEP), the overall system operation should be improved.

The goal of this project was to design a compliant and functioning water system for Treasure Valley that provides opportunities for system growth and expansion. Completion of this goal was achieved by accomplishing the five following objectives:

- Developed an inventory and description of the system
- Determined design criteria
- Identified constraints to system expansion
- Evaluated design alternatives
- Developed recommendations for future system operation and potential expansion

The system inventory and model of the existing features of the system was completed to determine what aspects of the Reservation should be improved. The project team determined design goals for the water distribution system, based on TVSR stakeholder input. Existing constraints and the capacity of TVSR's water distribution system were identified and added to the model generated to represent the factors for system growth and expansion. Costs of labor and materials were determined to provide various options for TVSR stakeholders to consider when enhancing the water system. The methods used in these analyses are presented in Chapter 3, and findings are included in Chapter 4. Design alternatives, developed and evaluated based on cost, time of installation, and feasibility, are included in Chapter 5. A set of final recommendations for what the project team believed were the most beneficial improvements or expansions to TVSR's water system are included in the final chapter of this report.

Currently, the water system at TVSR is focused on meeting present demand, but the limitations of the system raises concerns about the ability to meet projected future demands. An ideal water system for the camp incorporates plans for the future increase of camp attendance and creates processes for the documentation of maintenance procedures. An improved water

distribution system would enable the use of additional year-round campsites, increasing revenue and usage of the Reservation. A more permanent and resilient water distribution system would ensure that Treasure Valley could continue functioning in the event of a partial system failure. The health and reliable operation of these wells is key to the success of TVSR.

2.0 Background

This chapter includes information related to the history of TVSR and their water distribution system. An overview of TVSR and groundwater wells were included to establish a knowledge base for the project team. Relevant state and federal regulations were included to understand drinking water requirements for public water systems. Finally, TVSR's four wells are described to provide an understanding of existing conditions and history, and various pipe materials and specifications were researched to aid in the development of recommendations.

2.1 Treasure Valley Scout Reservation

The Boy Scouts of America operate ten councils in the state of Massachusetts, and the Mohegan Council manages the Boy and Cub Scouts of Central Massachusetts. This includes Treasure Valley and three regional districts: Massasoit, Hassanamisco, and Quinsigamond, spanning 30 towns in Massachusetts (Szafarowicz et al., 2013). Founded in 1925, TVSR provides a location for camping and experiencing the outdoors to Boy Scouts and Cub Scouts seasonally. After many years and numerous expansions, TVSR now operates 24 designated camping areas for Boy Scouts and recreational users (Szafarowicz, et al. 2013). The Reservation encompasses 1,600 acres of campground that is accredited by the Boy Scouts of America to provide a wilderness exploration program to young scouts in Central Massachusetts. Treasure Valley Reservation includes land in Oakham, Paxton, Rutland, and Spencer, Figure 1 below.

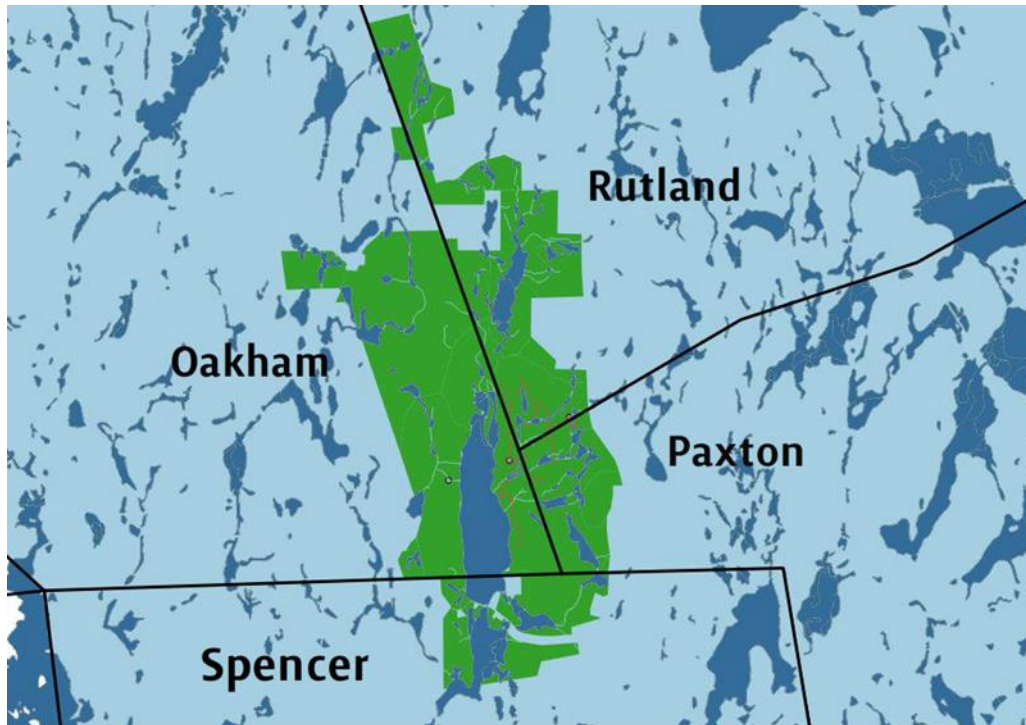


Figure 1: The location of TVSR, Oakham, Rutland, Paxton, and Spencer (Project Team, 2016)

Treasure Valley Scout reservation lies in the Chicopee River Watershed of Central Massachusetts and encompasses 723 square miles of land (Simcox, 1992). The reservation is located in the eastern portion of the basin and is shown in Figure 2. Water consumed by TVSR and its users is collected through the Chicopee Watershed. In order for TVSR to continue to provide clean drinking water from their groundwater wells, the health of the watershed must be maintained and protected by all users of this water resource. The existing wells of the Reservation meet all the present needs of the camp, but as demands on the water system increase, the ability of TVSR to supply safe drinking water is of utmost importance.

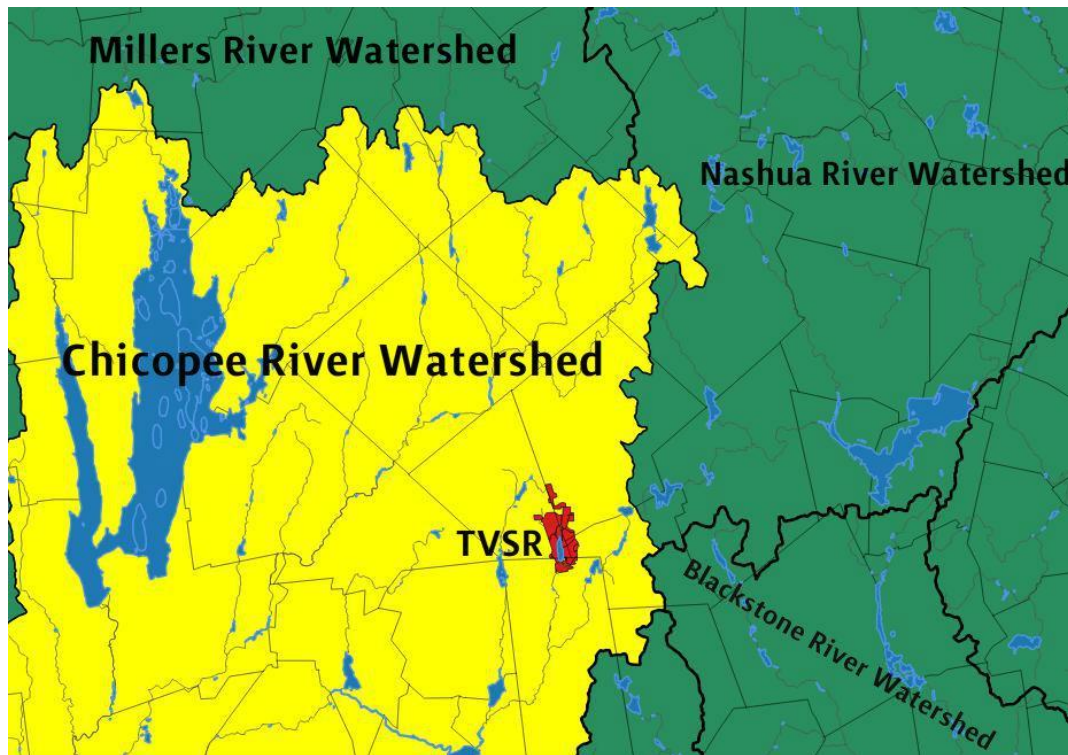


Figure 2: Location of TVSR within the Chicopee River Watershed of Central Massachusetts (Simcox, 1992).

The camp is divided into two major areas; Treasure Valley East and Treasure Valley West, which primarily serves the Cub Scout Program (M. McQuaid, personal communication, September 18, 2015). The reservation offers many ways to enjoy the landscape, including 70 miles of hiking and biking trails, shooting ranges, and Browning Pond, a 90-acre body of water that provides the scouts with opportunities for aquatic recreation (Mohegan Council, 2015). Treasure Valley is fully operational during the summer for Boy Scouts and provides opportunities for year round camping in East Camp. The Reservation generates its own drinking water from three groundwater wells on site, which provide campers with latrines, showers, and hot water for cooking and cleaning at most campsites (Mohegan Council, 2015).

Decisions made at the Reservation must pass through the Board of Trustees of Treasure Valley (Mohegan Council, 2015). The Board of Trustees of Treasure Valley is composed of three members and is responsible for overseeing the annual operation of the Reservation. Recently, the Board of Trustees has decided to pursue future expansion of Treasure Valley, such as the expansion and opening of new campsites, scouting activities, and other modifications to their water system. Enhancements of the water system was the primary objective of this report. This final objective provided TVSR with recommendations to the Board of Trustees of Treasure Valley for upgrades and expansions of their water distribution system. Previously, Treasure Valley had conducted a feasibility analysis of a fire suppression system.

In 1988, a water distribution study was prepared by Howland Engineering for Treasure Valley to determine and document existing conditions, made recommendations for improvements to the system, and explored the possibility of implementing a fire suppression system. This engineering study was referenced to determine the applicability of recommendations that were not completed and what, if anything, had changed since the study was issued. This study was used primarily as a reference point for new measurements collected by the project team in order to determine a change in performance of the system. Since the 1988 Water Distribution Study, the only substantial modification made to the water system has been the removal of a large storage tank in 2014.

2.2 Groundwater Wells

A groundwater well is a commonly used structure for providing rural and suburban communities with potable water. The size of the community is the most important factor when determining water needs for the installation of a well (Harter, 2003). Typically, wells are drilled vertically and are designed to access aquifers or groundwater sources, from which the water is

pumped up and passed through a filtration system and then distributed through the water network. Well pumps have a general design life of over 50 years, depending on various factors and water usage (Conway, 2013). This makes it necessary to record installation and maintenance dates on all pumps so that replacements and repairs can be made on a regular basis.

Structurally, groundwater wells should be designed to last 50 years or more, free of contamination and capable of withstanding the pressures of the earth (Harter, 2003). Typical water supply wells consists of a bottom pump, well screen, and well casing surrounded by a gravel pack. Water flows through the well screen which is designed to keep sand and gravel from infiltrating the water supply well. The gravel pack is constructed to keep sand and fine particles from moving into the well. The pump is housed by a well casing which provides a pathway from the aquifer to the surface (Harter, 2003).

2.3 Drinking Water Regulations

A large amount of people in the United States receive drinking water from public water systems. According to the U.S. Environmental Protection Agency, a public water system is classified as a system that provides water for human consumption through pipes or other constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year (310 CMR 22.02, 2009). As of 2010, about 87,000 of these types of public water systems serve 13.1 million people in the United States (United States Environmental Protection Agency, 2012). A public water system can be further classified into a Community Water System, a Non-Transient Non-Community Water System, and a Transient Non-Community Water System per the Massachusetts DEP (MassDEP, 2009a). TVSR is classified as a public water system according to Environmental Protection Agency guidelines.

Within the Commonwealth of Massachusetts, TVSR is classified as a Transient Non-Community Water System (TNCWS). As defined in Mass DEP Drinking Water Regulations, a Transient Non-community Water System is a “public water system that is not a community water system...with at least 15 service connections or serves water to 25 different persons for at least 60 days of the year” (310 CMR 22.02, 2009; (Gates, 2015).

Potable water sources in Massachusetts are regulated by MassDEP under 310 CMR 22.00 (310 CMR 22.01, 2009). These regulations were created to ensure that public water systems provide safe, fit and pure water for consumption by residents and visitor of the Commonwealth of Massachusetts. As a TNCWS, TVSR is subject to all rules and regulations contained within 310 CMR 22.00. Recent MassDEP sanitary surveys have raised concerns over the enforcement of Zone I radii and IWPA radii at two of TVSR’s three operational wells (Gates, 2015). Therefore a deeper understanding of the regulation was required by the team in order to determine appropriate and compliant recommendations for TVSR.

A Zone I Radius is define by DEP as the protective radius required around a public water supply well or well field (310 CMR 22.02, 2009). This radius is determined by the following equation:

$$\textit{Zone I radius (feet)} = 150 * \log(\textit{pumping rate (GPD)}) - 350$$

If the well is not operational, the Zone I radius is 100 feet (310 CMR 22.02, 2009). The other radius typically applied to a well or well field is a Zone II radius, which refers to the area of an aquifer that would contribute water to well under the most severe pumping and recharge conditions (310 CMR 22.02, 2009). As DEP has not approved a Zone II radius for TVSR, DEP created Interim Wellhead Protection Areas (IWPA) around each of TVSR’s wells. The IWPA

area for a well is calculated by using the pumping rate, in gallons per minute (GPM), as shown in the following equation:

$$IWPA\ radius\ (ft) = 32 \log(pumping\ rate\ (GPM) + 400$$

Usage within these zones is restricted to activities “directly related to the provision” of drinking water that “will have no adverse impact on water quality” (MassDEP, 2009b). Passive recreational uses, for example walking and hiking, are presumed to have no adverse effects on drinking water and therefore are permitted within Zone I and IWPA radii. Potential sources of contamination, including septic fields and toilets, are considered dangerous to public water supplies due to the chance of rupture or spillage, and would not be permitted in Zone I’s.

Sources of contaminants are prohibited within Zone I radii due to the presence of Coliforms and other bacteria. Coliform bacteria are considered an “indicator” organism because both the bacteria and other dangerous pathogens come from fecal matter (New York State Department of Health, 2011). Having a high coliform bacteria concentration means there is fecal matter present. According to experts, it is more efficient to test for coliform bacteria rather than perform multiple tests for each dangerous pathogen that exists (New York State Department of Health, 2011).

The most stringent regulations enforced on TVSR are pathogenic and contaminant related, as there are very miniscule amounts of contaminants allowed in drinking water that is considered safe for consumption. Some of these rules have limited the functionality of the camp and provide strict guidelines in forming a baseline for improvement. The Safe Water Drinking Act gives the EPA the authority to create regulations for drinking water of either maximum contaminant levels or maximum contaminant level goals (*The Safe Drinking Water Act*, 2002). The Total Coliform

Rule regulates coliform bacteria, which are used as “surrogate” organisms to indicate whether or not system contamination is occurring (*The Safe Drinking Water Act*, 2002).

Lastly, TVSR is spread over four towns in Massachusetts. Located within the four towns of Oakham, Rutland, Spencer, and Paxton, Treasure Valley must abide by all of the regulatory laws each town enforces. To simplify the regulatory process, the Oakham Board of Health was selected by an agreement between TVSR and the towns to represent the other three towns when working with the Reservation in regards to their water resources (T. Chamberlain, personal communication, September 18, 2015).

2.4 Well Regulations

To drill and construct a new private well in the Commonwealth of Massachusetts, multiple regulations and conditions must be met by the driller and supplier of the well. All potential sources of contaminants within 200 feet of the proposed well location must be identified (Tomlinson, 1989). The well site should be located up gradient from the surroundings and easily accessible in order to facilitate repair and maintenance of the site.

After a well has been sited, the next step in the process is the completion and submittal of all applicable permits. These permits ensure that no new buildings will be constructed without a readily available water source (MassDEP, 2009b). Additional required permits are included in the following list:

- private well construction permit
- plumbing permit
- private well alteration permit
- renewable private well use permit
- permit for decommissioning abandoned wells, test holes, and inadequate borings

These permits are designed to allow Massachusetts the opportunity to evaluate a proposed well site to identify special water quality monitoring requirements or past water quality issues at areas nearby (MassDEP, 2009b). Application and submission of these permits for TVSR would happen via the Oakham Board of Health, as local towns are encouraged by DEP to create a process for the handling of private water supplies (Tomlinson, 1989).

As of June 2009, well regulations for all new TNCWS's with less than 10,000 gallons per day received new criteria that must be followed (MassDEP, 2009b). During pre-submittal meetings with DEP, maps of the proposed well area with the approximate locations of Zone I radii, along with current and future land uses surrounding the well, must also be included in order to begin the approval process. These regulations ensure that public drinking water will not be adversely impacted by activities surrounding the well. Passive recreational uses, defined as walking, hiking cross-country skiing, bicycling, and horseback riding, do not adversely impact water quality according to MassDEP (MassDEP, 2009b).

The amount of water which can be withdrawn from any well must be approved, registered, or permitted by MassDEP, and the necessary permit, BRPWS37, must be completed and submitted to DEP. Cross sections of the well, proposed depth and other dimensions, any form of treatment, surveyed plot plan of the Zone I radius, and an affidavit with the registry of deeds must also be included with the permit in order to obtain approval, as identified in the specification section of the Private Well Guidelines (MassDEP, 2009b). Additional requirements for well construction, if applicable, are specified in Sections 4.5, 4.6, and 4.20 of Guidelines and Policies for Public Water Systems (MassDEP, 2016b).

2.5 Treasure Valley's Wells

In order to adequately map and propose improvements to the groundwater well system of Treasure Valley, a full understanding of the history behind each well is essential. This section details the four wells presently located on the Treasure Valley Reservation.

The first well, known as the Farmhouse Well, has a chlorine bleach drip to treat high bacteria levels. The East Lodge Well has a high iron and manganese count, and the West Lodge Well has low water draw. The Boonesville Well is the fourth well and has not been used since the late 1980s. All four wells are circled in red, displayed in Figure 3.

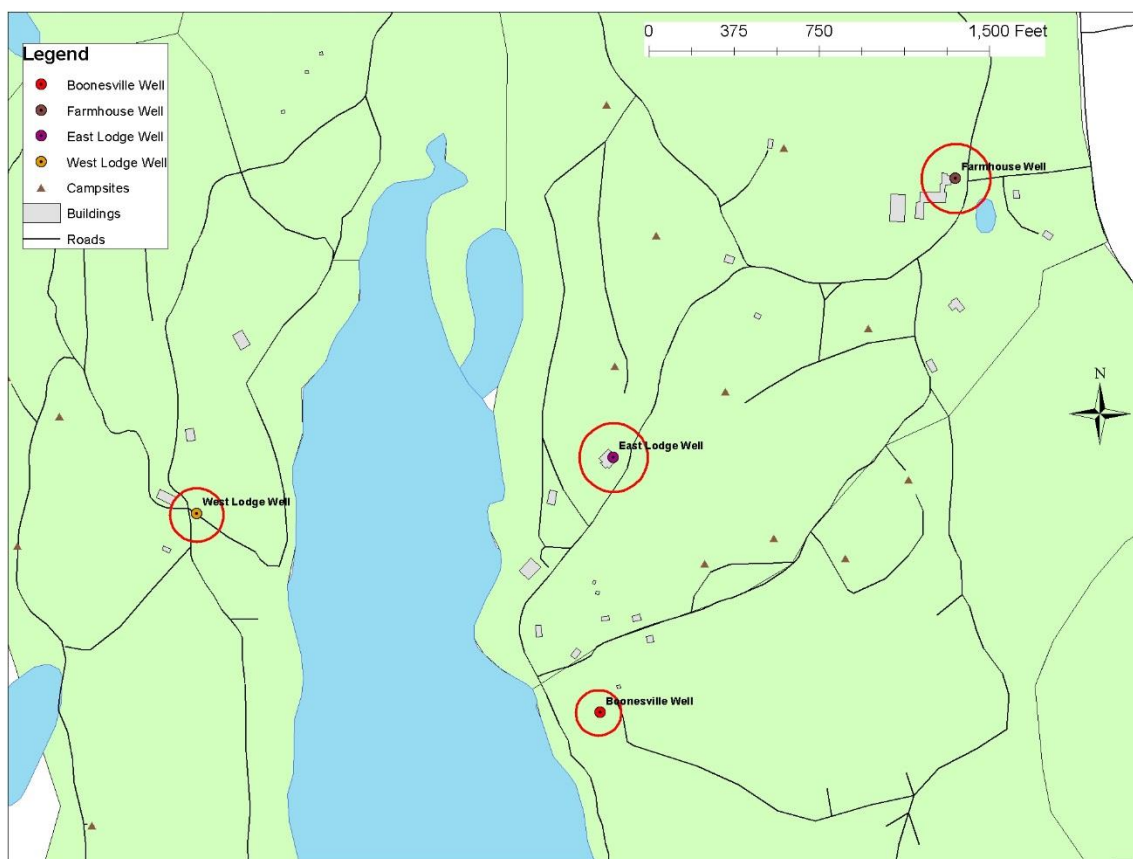


Figure 3: The location of the 4 wells of Treasure Valley (Project Team, 2016)

2.5.1 Boonesville Well

The Boonesville Well is located on Boonesville Plains near Browning Pond. Boonesville Well is a six inch diameter well, drilled to a depth of 140 feet. Water is pumped from a depth of approximately 130 feet by a one-horsepower pump. As the well is not currently in service, Boonesville has a default Zone I radius of 100 feet and an IWPA radius of 500 feet (Gates, 2015).

This well supplied the East Lodge water distribution system with groundwater, but was disconnected from the East Lodge system in the 1980s due to decreased demand. Historically, this well was used to supply a large fiberglass tank in West Camp via a PVC pipe approximately three inches in diameter underneath Boonesville Plains to a point just north of Carr Waterfront. From there it continued under the pond. At the West Waterfront, there is a service pit where the PVC line fed into a fiberglass water tank that supplied the campsites and shower house of West Camp.

The Boonesville Well and associated piping system have been unused since the closing of West Camp as a resident camp in 1979 (M. McQuaid, personal communication, September 18, 2015). The pipe manifold outside the Boonesville Pump House has connections which have the ability to supply the East Lodge water distribution system, but the well produces water at such a high pressure that it has historically blown apart the fittings on the manifold, the well is shown in Figure 4. For this reason, the well is kept offline and unused by TVSR. Since the well has been shut down the remaining pipe above ground has been largely removed, but the underground portions still exist (M. McQuaid, personal communication, September 18, 2015).



Figure 4: The Boonesville Well, present day (Photo, 2015)

2.5.2 East Lodge Well

Located below the kitchen of TVSR's East Lodge, the East Lodge Well is a six-inch diameter bedrock well drilled to a depth of 230 feet. Water is pumped from a depth of approximately 220 feet with a 0.75-horsepower pump, and pumps an average of 2,221 GPD. East Lodge Well has a Zone I radius of 152 feet and an IWPA of 449 feet (Gates, 2015). East Lodge's well is used on a seasonal basis during the peak summer months for TVSR and is shown in Figure 5. The well also fills the storage tank below East Lodge kitchen before it was decommissioned.

Due to the location of East Lodge Well, the well is inaccessible for alteration, but has the most advanced pump and monitoring system in the camp. The well has a variable pump pressure monitoring system that provides data on the pressure in the well in real time (M. McQuaid, personal communication, September 18, 2015). Any changes or alterations to the well in East Lodge could conflict with existing building regulations, due to the physical location of the well. These regulations could prove prohibitive to any modifications or upgrades to East Lodge or the East Lodge Well, as the regulations could require a substantial investment on behalf of TVSR in order to remain compliant.



Figure 5: East Lodge well, located in East Camp of TVSR (Project Team, 2016)

2.5.3 The Farmhouse Well

The Farmhouse Well, located in the Farmhouse of TVSR, is shown in Figure 6. The well is a six-inch bedrock well, drilled to a depth of 110 feet. Water is pumped from an approximate depth of 100 feet with a 0.75-horsepower pump. The Farmhouse Well has a Zone I radius of 153 feet and an IWPA radius of 450 feet, and supplied approximately 3,229 gallons per day in 2014. This is the only well at TVSR equipped with emergency power (Gates, 2015).

The Farmhouse Well supplies the Farmhouse/Training Lodge, King Cottage, Director's Cottage, Ranger Station, Health Lodge, Shooting Range, Econ Camp spigot, and campsites: Madore, Baden-Powell, and Tall Maples. This well also fills the water storage tank in the basement of Farmhouse. This well had a chlorine treatment system as identified in the 1988 Water Distribution Study conducted by Howland Engineering, which has been offline since 2014 (Howland Engineering Inc., 1988).



Figure 6: Farmhouse well, located next to the Farmhouse building of TVSR (GIS, 2016).

2.5.4 West Camp Well

West Camp is serviced by one well, located on the south side of the Conference Center of TVSR. Like the other wells at TVSR, West Camp's well is a six-inch bedrock well, drilled to a depth of 135 feet. Water is pumped from a depth of approximately 125 feet by a one-horsepower pump. The well has a Zone I radius of 119 feet and an Interim Wellhead Protection Area of 430 feet. In 2014, West Camp's well pumped approximately 781 GPD (Gates, 2015). The well provides drinking water to West Lodge and the Cub Scouts Day Camp Building and various activity fields, the well is shown in Figure 7.

The well lies on a hill and is enclosed in a cement casing. The well has a low pull, as well as problems with contaminants such as iron and manganese. This well is connected to hydro pneumatic tanks located underneath the West Lodge (M. McQuaid, personal communication, September 18, 2015). This system has the capability to connect to the Boonesville system via a long pipe that runs under the pond, but currently remains independent as the water demands for West Camp have fallen over the years.



Figure 7: The West Lodge Well of TVSR's West Camp (Project team, 2016).

2.6 Tools for Data Gathering and Representation

Tools used for data gathering included phone applications, geo-referencing software, and open source software programs. Together, the project team utilized these tools to conduct an inventory of TVSR's water distribution system and generate maps of relevant data for analysis. A description of each is included in this section, as well as information on how to access the programs for future use.

Map Plus is an application for smart phones that takes GPS coordinates at a user's present location. This application, created by the company Miocool, maps a line by taking GPS coordinates every 50 feet and connecting the points while also providing the distance between the two (Miocool, 2015). In addition, pictures taken at a specific coordinate are geographically linked to that location. Popular online maps such as Google Maps, Bing Maps, and various kinds of image files are used to display these data. Data collected can be exported as KML, KMZ, or GPX files, all compatible formats with QGIS and ArcGIS.

ArcGIS is a program developed by a company called ESRI in order to create dynamic layers on maps to visualize and make conclusion about data. The program has an extensive functions from plotting points using GPS coordinates on a real time map to creating layers that display polygons, representing geological features such as lakes or ridges. Different conclusions can be drawn with these interactive maps, such as distances between points, created general trends, and planned future development or modification to the landscape. Shapefiles, a file format utilized by GIS, can be created and shared for open access (ESRI, 2010).

Quantum Geographic Information System (QGIS) is an open source software package developed by the Open Source Geospatial Foundation. While QGIS is not as robust as ArcGIS, it is useful as a smaller software package to view and edit shapefiles. QGIS is able to run on many operating systems and supports numerous vector, raster, and database formats and functionalities.

This program can visualize, manage, edit, analyze data, and compose printable maps. It has a simplistic design so anyone can download and use it, even if they do have formal training in geo-referencing software (Open Source Geospatial Foundation, 2016).

2.7 Network Factors

QGIS and ArcGIS were utilized to create representation of the water distribution network of TVSR. After the creation of GIS maps, the pipes were given attributes based on their physical characteristics. The material of the pipes are important from a cost perspective while also considering material properties. The galvanized steel used in the Farmhouse Well system was examined by the project team as well as alternative materials such as polyvinyl chloride (PVC), chlorinated polyvinylchloride (CPVC), and polyethylene (PE). Galvanized steel is a more traditional type of material and has been used in many systems. These types of pipes are often joined by threaded connections and are restricted in their range of use due to their rigidity. There have been problems with using these types of pipes due to internal corrosion which adds iron to the water running through them. This problem is exacerbated when the water in the pipes goes through periods of slowed or static flow.

PVC pipe is widely used in piping material. In terms of size and weight, PVC is comparably lighter than galvanized steel. PVC is not as susceptible to corrosion, but is more likely to suffer from physical damage. In addition, extreme cold can cause the piping to become brittle, while extreme heat can cause it to deform. The most common use of PVC worldwide is for drainage and storm water management.

CPVC, is PVC that has been polymerized with chlorine to create a more durable thermoplastic. This material has many of the same properties as PVC, but can withstand a larger range of pressure and temperature without complications. CPVC is more resistant to corrosion and

fire retardant. PE has many of the properties of the other materials, but it is categorized by density. Pipes with a greater density are capable of handling larger pressures, but with an increase of rigidity. PE is primarily used for drainage and is able to withstand higher temperatures than other types of materials (World Health Organization, 2006).

Ensuring that pipes can withstand varying temperature ranges is important when construction a permanent water system. A key factor to consider during construction of such a system, is the general frost line of the area. The frost line of an area is the maximum depth in which soil will freeze. This depth is important to know when burying the pipes. The pipes need to be below the frost line to keep the water running through from freezing. According to Massachusetts Regulations, four feet has been established as the minimum depth to ensure pipe is below the frost line (780 CMR 1809.5, 2009). This is the recommended depth to dig to when burying the pipes to establish a winterized pipe system.

3.0 Methodology

This section describes the methods used throughout this project to analyze the water distribution system of TVSR. The goal of this project was to design a compliant and functioning water system for Treasure Valley that provides opportunities for system growth and expansion. The results of this project were delivered to TVSR to enable stakeholders to assist in decisions about TVSR's future.

By conducting an inventory of the water distribution system as a preliminary way of organizing all available resources, outstanding gaps in the system were identified. Potential improvements based on collected geo-referencing data were separated into short and long term projects, with the intention of keeping TVSR's water resources aligned with camper attendance. To accomplish this goal the following five objectives were completed by the project team:

- Inventory and model existing features of the system (Subsections 3.1 and 4.1)
- Determine design criteria for the water system, based on client's needs (Subsections 3.2, and 4.2)
- Identify existing constraints to system expansion (Subsections 3.3, 4.3, and 4.4)
- Evaluate design alternatives to the water distribution system (Subsection 4.4)
- Provide recommendation for future system operation and potential expansion (Subsection 5.0 and 6.0)

3.1 Water Distribution System Inventory and Model

A multi-phase plan was created by the project team to inventory the water distribution system. The phases included acquisition of information, identification of assets at various buildings, as well as useful recommendations on how the camp should be maintained and designed for the future. Taking a full inventory of the water distribution network was the first step in designing a more efficient system.

The first phase of the inventory consisted of discussions with Mike McQuaid and Ranger Matt of TVSR. These discussions focused on the physical location and current status of the water distribution system. The project team examined hand-drawn historical maps of the water network and transferred the data to GIS for future reference.

The second phase of the inventory process entailed the identification of wells, pumps, and hot water boilers at each campsite and building. This information was collected through site visits and documented in photographs taken by the team.

The third phase of the inventory consisted of physically walking along the pipes of TVSR and collecting GPS data. This information was collected with the assistance of the Map Plus software package for the iPhone. This software allowed the project team to take photographs of connections, joints, and shut off valves for each piping network, allowing the project team to identify key locations in the representation of the water distribution system.

The final phase of the inventory plan was to compile the GPS data that had already been generated using ESRI's ArcGIS software package. QGIS allowed the project team to use personal computers without the need for licensed software. The files created in QGIS were transferred to GIS for further editing. Geospatial information included well location, well types, pipe size, pipe locations, pump types, water storage tank locations and sizes, and unused pipe locations. All

components of the water infrastructure were accounted for in GIS to create a base model of the water network.

3.1.1 Field Data Development

To further the initial model created by the project team, field surveys were necessary. These field surveys provided a more complete knowledge base of the water system. The survey data was combined with physical maps of TVSR in order to geo-reference existing faucets, spigots, and pipes of TVSR. This data was compiled into ArcGIS through the use of the Map Plus application. Pictures taken at start and end points of each pipe, as well as at all visible valves and splits, were recorded in GIS. The locations of buildings, campsites, and roads were compiled from maps to display the water distribution system of TVSR in detail.

On Wednesday, October 21, 2015, the project team collected data on campsites, wells, and water system components. Mr. McQuaid provided information on water accessibility at campsites, which campsites had access to hot water services, as well as other relevant well information that was then compiled and included in the model of TVSR's water system.

In regards to campsites, it was necessary to identify which areas were already serviced by water and which areas needed incorporation into the network. Areas of the camp that have hot water units were identified, and other existing infrastructure features were noted. Existing piping specifications: diameter, length, and functionality were recorded added to the attribute tables in GIS. Information on wells such as depth, lining type, and service history was collected. This information, coupled with the specifications for each pump, provided accurate flow measurements and allowed the team to calculate the water draw of the TVSR network.

The project team followed all visible connections and branches of the network, taking photographs along the way, while also documenting shut off valves and splits in the pipe.

Permanent and auxiliary connections leading from each well were identified and recorded. These raw data were uploaded into QGIS to provide a detailed representation of the water distribution system. A more accurate and comprehensive version of the map was created in ArcGIS for further analysis.

After this initial visit, the project team returned to TVSR to measure the depth to water of each well. To measure the depth to water, the project team borrowed a depth gauge from the Massachusetts Department of Conservation and Recreation (MA DCR). After the wells were uncapped, the depth gauge was inserted into the well and lowered until the sensor detected water. The depths were recorded and used to establish the level of the water table. During the visit, the project team was able to measure a flowrate from a spigot connected to the Farmhouse Well. The team was able to use this data, coupled with pipe diameters, to estimate the water velocities of the Farmhouse Well system. Other velocities were assumed based on similar pump configurations.

During the data collection phase, the project team examined pre-existing model drawings of the water network, as well as computer generated maps to assess current conditions. The photos taken of key components were transferred in the form of a KMZ file and projected on QGIS. The coordinates of the pipe network were saved as a polyline shapefile and displayed on ArcGIS. These pictures are linked to their respective coordinates in GIS and can be accessed with the HTML selection tool.

Other water infrastructure data and factors that impact the pipe network were collected with the assistance of members of TVSR. Maps provided by Mr. McQuaid were specific to septic locations at TVSR. These maps can be found in the Appendix B and C. The septic system map identified locations of septic system components including seepage pits, septic tanks, and leaching

fields. In addition, the project team utilized shapefiles created by previous MQP teams to gather and collect additional data.

3.1.2 GIS Data Collection

The collected data was compiled to create a visual representation of the water infrastructure network. The GPS coordinates gathered were displayed on ArcGIS and provided more precise locations of the pipe system. The photos taken of shut off valves and connectors were saved in the team's project folder and hyperlinked to a point shapefile viewable by clicking on the data point with the HTML pop-up tool in ArcGIS. The points were also labeled in the attribute table so each point and corresponding picture could be identified for future use.

By analyzing a hand drawn map of the water infrastructure (see Appendix C), gaps were identified in the pipes that were not located by the project team. These pipes were assumed underground or missing and were drawn in by the project team on the GIS map. This polyline shapefile is separate from the collected pipe data and labeled as "Underground_Missing_Pipes" in the project files. In addition, the diameters of all the pipes shown on the hand drawn map were labeled as such on the shapefile file displaying the full network of pipes.

Mr. McQuaid provided the project team with a hand drawn map of the septic systems located at TVSR that was scanned and saved as a PDF. This file was imported to GIS and made into a shapefile. The image was geo-referenced to match with the GIS shapefile of the Reservation. Polygons were drawn over the locations of the septic systems in order to create a compatible GIS map to display the locations of sewage disposal sites. The polygons were labeled as leaching fields, septic fields, seepage pits, etc. Using the Buffer tool, a form a geo-processing, an additional layer was created to show the distance away various parts of the water infrastructure should be based on Massachusetts Title V regulations.

3.1.3 GIS Data Analysis

The data that were compiled and projected in ArcGIS provided the team with a visual to initiate the planning phase of the project. A major component of the project involved the identification of possible new well locations for the Reservation. By utilizing GIS's ability to create buffers around obstacles, open areas where wells could be drilled were identified on the map of the Reservation. These new well locations are in compliance with all known buffer regulations.

The many maps created in ArcGIS by the project team illustrate the locations of components of the sewage disposal sites of TVSR. By overlaying the septic system shapefile with the locations of existing water infrastructure, conclusions were drawn with regards to the regulatory compliance status of the Reservation. This was accomplished with the application of buffers around the septic components added to the base GIS map. Buffers were also created using the IWPA distances to evaluate whether the existing wells at TVSR met regulation. Buffer layers were created on ArcGIS to represent zoning constraints in relation to groundwater wells. By applying these regulatory distances to surface water, buildings, and roads additional buffer layers were created. These various buffer layers were combined into one shapefile using the Merge function of GIS. These visuals assisted in the overall evaluation of TVSR's current water infrastructure.

In addition to GIS layers, the water table of TVSR was determined for further analysis. The team took measurements of the depth to water of each of the wells and was created a profile view of the water table. This profile was used to determine the depth a new well should be drilled. The next step of this project was to determine the operational goals which TVSR sought to achieve through the completion of this project.

3.2 Water Supply Budget

Meeting the goal and objectives of this project required the generation of recommendations on the water supply capacity of TVSR. To provide recommendations for the Reservation, estimates were needed on the amount of water TVSR currently uses, as well as the amount of water used at peak capacity. Goals of TVSR were determined through questions posed to stakeholders of TVSR, as well as through internal discussions of the project team. Questionnaires were compiled from Mike McQuaid, Chair of the Properties Committee of TVSR, Tom Chamberlain, Vice President of Camping TVSR, and Warren Bock, Trustee of TVSR. Similarities and differences in views were documented and analyzed to develop achievable goals for the project team to pursue. These responses centered on the overall improvement of the water distribution system of TVSR for future prosperity of the Reservation.

The first step in this process was the determination of the maximum amount of people that TVSR could serve at one time. These estimates only assumed the seasonal camping usage and excluded other year round uses of the camp, as relevant data was limited. The Reservation provided estimates for the amount of people each camping site could hold. The total capacity was determined by the summation of all campsites and buildings. The American Water Works Association created guidelines for campers and campsites based on the estimated water usage per person in a given day (American Water Works Association, 2008). By multiplying this total by the average amount of water each water feature uses, the maximum water usage of each day and overnight camper was determined. The results of this calculation were then combined with the total amount of campers to determine the maximum water demand of the camp based on maximum capacity. This served as a guideline for future recommendations and is shown in the following equation:

$$\text{Max Water Demand} = (\text{Max Campsite Capacity} + \text{Max Building Capacity}) * \text{Average GPD}$$

3.3 Design and Evaluate Modifications to the System

Modifications to TVSR's water distribution system were determined through discussions with project advisers and TVSR stakeholders. Modifications to the current system were analyzed for their effect on the operational capabilities of TVSR, as well as ease of implementation and cost effectiveness. Each modification was given a value based on the cost, constructability, and desirability of the proposed alternative. This established a method to determine the feasibility of each modification based on the scoring rubric generated by the project team. Feasible modifications consisted of low scores in each of the three categories, yielding a low total in the feasibility column of the rubric. The five modifications with the lowest scores were chosen for future study.

The project team began evaluating the several different scenarios and recommendations for TVSR after the initial data collection period. Evaluations were based on a rubric composed of important and relevant criteria as identified by the project team and TVSR stakeholders. This rubric was based on categories such as cost, time, feasibility, and desirability of each alternative. Each of these categories had a varying range of points that could be assigned from specific categories based on the importance of that category to the camp. These responses were then combined with the project team's experience and led to the formulation of the final recommendation for TVSR, where each modification was scored according to the rubric generated throughout the project.

To complete the rubric, the project team established several possible modification options for the water system based on the initial goals and objectives of TVSR. In order to address the stakeholder's thoughts regarding these options, a survey of ten modifications for TVSR's system

were distributed to six stakeholders at a preliminary presentation on February 10, 2016. The survey also included the option for stakeholders to write in their own modification(s) if the list was incomplete. This survey asked the stakeholders to rank the various modifications on a scale from one to eleven, with one being the highest, to determine which modifications each stakeholder felt was the most important to TVSR's future. This scale was then converted to a value between one and three to identify similarly ranked modifications by TVSR stakeholders. One was the cheapest, most time effective, and most desired value, while three was the lowest value. The different ranks were used to determine the pertinence of the modifications to TVSR. The blank survey is shown in Figure 8 and the blank rubric in Figure 9. The compiled survey response data can be found in Appendix D of this report.

TVSR Water System Modification Survey

Name: _____

Title: _____

Please complete the following questionnaire with specific regard to the above enquiry, by ranking the following modifications from 1-11:

Modifications	Rankings 1-11
Well relocation	
Well contamination treatment	
Replacing existing piping	
Winterizing pipe system	
Moving septic fields	
Relocation of East Lodge	
Implementation of storage tanks	
Do nothing to the existing water system	
Fire suppression system	
Water system expansion	

Please write any further comments on the back of the page

Thank you for your help

Figure 8: The blank survey distributed on February 10, 2016.

The estimated cost and time of each modification were determined by the project team and scored in a range from one to four, to provide greater weight to these aspects of constructability. The modifications were given similar scores if their costs and labor hours were similar. Finally, the project team ranked the modifications based on the ‘perceived pertinence’ of whether or not the modification listed would have a positive effect on TVSR. These scores were combined with the stakeholder responses to create the pertinence category. These three categories were then added together to produce a composite score for each modification. From this sum, the recommendations were ranked from lowest to highest to determine which modifications required further study by the project team. This list forms the basis of the design alternative section.

	Cost	Time	Pertinence	Feasibility
Well relocation				
Well contamination treatment				
Replacing existing piping				
Winterizing pipe system				
Moving septic fields				
Relocation of East Lodge				
Implementation of storage tanks				
Do nothing to the existing water system				
Fire suppression system				
Water system expansion				
Ranges for cost (\$\$): 1: 0-15,000 2: 15,000-25,000 3: 25,000-50,000 4: 50,000+				
Constructability (time): 1: 1-2 weeks 2: 1-2 months 3: 3-6 months 4: 6+months				
Pertinence (desirability): 1: desirable 2: moderately desirable 3: least desirable				
<i>Figure 9: The blank rubric used to rank and score modifications for TVSR.</i>				

Once scored, these modifications to TVSR's water distribution system were compared based on material and labor costs, as compiled by RSMeans (Babbitt et al., 2011). Relevant data was compiled by the project team and totaled to determine the most cost effective options for TVSR. This data, located in Appendix E of this report, provides a breakdown of the estimated labor and material costs for each material, as well as the total estimated cost of modifications to the above and below ground pipe networks. Using this data and other cost estimates, the project team determined which modifications were the cheapest and most expensive options for TVSR to consider. The best modifications for TVSR to consider, based on the project team's analysis, are located in Section 6.0.

4.0 Findings

Important factors included the existing network conditions, regulatory and physical constraints, and new system costs. These factors were reviewed and evaluated in order to shape design alternatives and recommendation for for the Treasure Valley Scout Reservation (TVSR), GIS models were created by the project team to establish an inventory of the water distribution network. The current water demand was calculated from the 2014 Sanitary Survey of TVSR to determine the maximum allowable pumping rate for each well. Design constraints, involving applicable buffers and regulations, were compiled to determine TVSR's compliance with MassDEP. Finally, the labor and material cost estimates for proposed improvements to the system were calculated to provide further detail to TVSR stakeholders. Using these findings of the analyses, the project team was able to research and design recommendations and improvements to the existing infrastructure that can easily be expanded as TVSR grows.

At the time of preparation of this report, TVSR wanted to increase their attendance and revenue streams in order to extend the longevity of the camp and strength of the scout program (T. Chamberland, M. McQuaid, W. Bock, email correspondence, October-November, 2015). To accomplish these goals, TVSR needs to improve the resiliency of their water distribution system to avoid failure. Therefore, it was necessary for the project team to identify weaknesses in the existing water system and generate design alternatives to the current problems the Reservation faces. These alternatives were discussed with stakeholders to determine their pertinence to TVSR.

4.1 Water/Wastewater System Inventory

Presently, the TVSR water distribution system consists of three functioning wells, eight faucets, 6,084 feet of winterized pipe, and 13,268 feet of seasonal piping during peak months. The system serves a total of 19 buildings and 13 campsites for daily and overnight visitors to the

reservation (ArcGIS data compiled by project team). The existing infrastructure of TVSR is illustrated in Figure 10 and was compiled during the course of this project.

Figure 10 illustrates the existing water lines and campsites of TVSR. The underground pipes displayed in green were not identifiable and their location represents the team's estimate as to where the pipes should be according to historical maps of TVSR. The four wells of TVSR are noted as light blue squares in Figure 10 and are each connected to an independent water distribution system.

Sewage at TVSR is handled by a combination of septic tanks, leaching fields, and vaults (also known as tight tanks), according to maps of the reservation, which can found in Appendix B. Figure 11 is a GIS map of the sewage facilities the project team collected. This information was used to gain an understanding of all water related systems at TVSR.

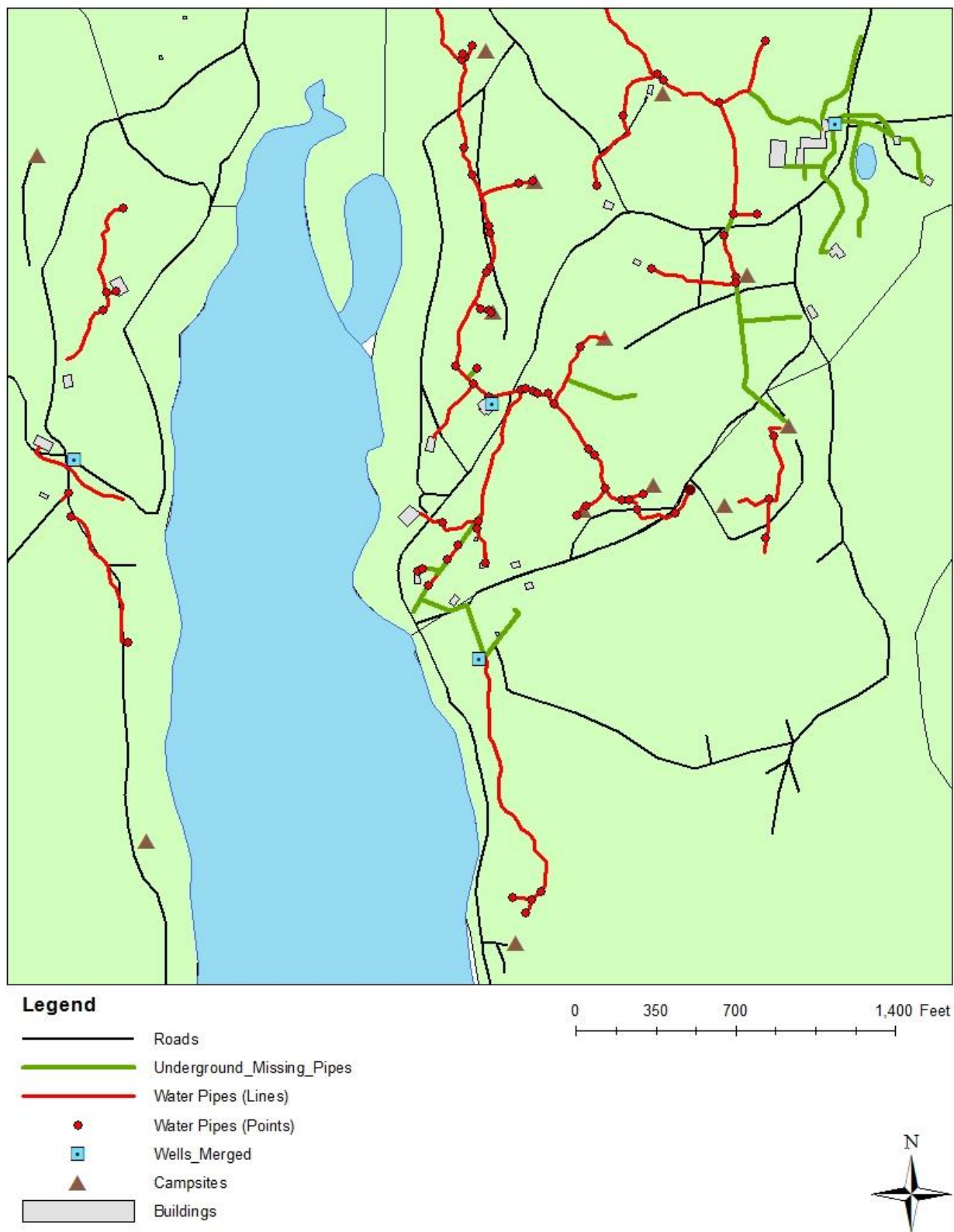


Figure 10: Existing water distribution system of TVSR, as determined by the project team

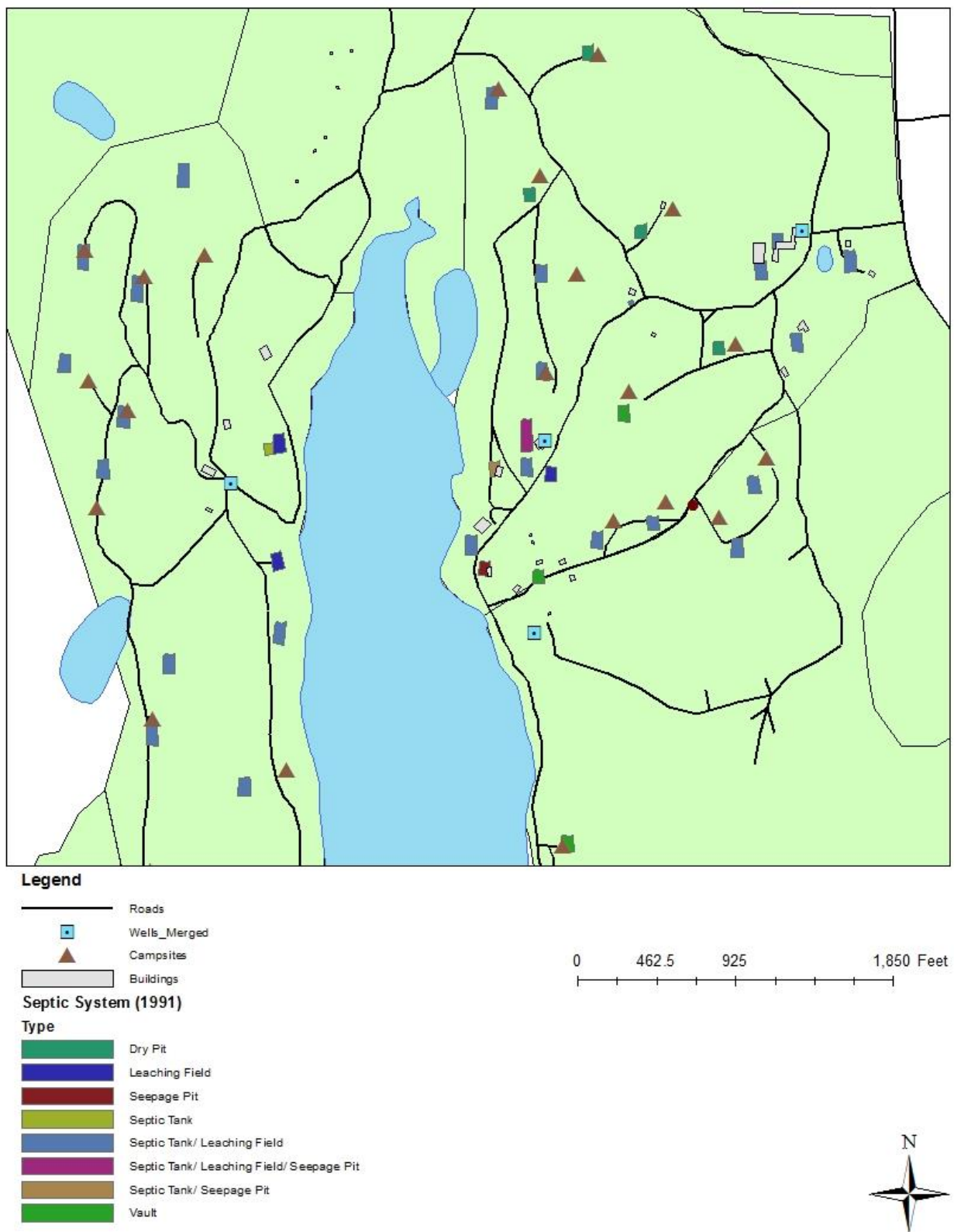


Figure 11: Map of the existing sewage disposal systems at TVSR

4.1.1 Current Pipe Network

The water distribution network of TVSR consists of the three active well sites, a series of pipes that run both above and below the ground, and other infrastructure including shut-off valves, three-way tees, and faucets. In total, TVSR has over 20,000 feet of pipe network that runs throughout the reservation. Approximately 70% of the piping is above ground as extrapolated from Table 1.

Table 1: Length of piping at TVSR			
System	Above Ground (feet)	Below Ground (feet)	Total (feet)
West Well	2,050	0	2,050
East Well	7,740	1,540	9,280
Farmhouse Well	4,200	4,540	8,740
Total	13,990	6,080	20,070

The above ground piping is made of flexible PVC to accommodate uneven terrain. The underground piping is primarily localized to the Farmhouse system and is made of galvanized steel. These pipes are buried underground and supply the Farmhouse system with water year round as opposed to the flexible PVC that is shut off and drained in the offseason. Since the underground piping is buried, the only way of knowing the location and sizes of pipes is by use of the hand drawn maps from Ray Hunt shown in Appendix B and C. This map was also used to determine pipe diameters of the network.

TVSR's pipe network contains pipes with diameters ranging from 0.75-2 inches. Some of the network's pipes are of unknown diameter in the West Camp system because these were destroyed after the hand drawn map was created. Since the main focus of the project was the East Camp network of pipes, the total lengths of pipes were compiled for each diameter. These data can

be seen in Table 2. There are other components to the water infrastructure that were accounted for such as three-way connectors, shut-off valves, and connectors. The total amount of each component in the system is outlined in Table 2.

Table 2: East Camp's Pipe Network					
EAST CAMP	3/4"	1"	1 1/4"	1 1/2"	2"
Above Ground Pipe Length (feet)	6,533	793	1,802	2,656	155
Underground Pipe Length (feet)	2,963	0	1,563	856	704
Three-Way Connectors	12	2	5	10	2
Shut-Off Valves	5	2	1	3	0
Connectors	4	0	2	4	1

TVSR has an extensive piping system that includes many service connections at each of the campsites. The system will have different energy losses throughout resulting in fluctuating water velocities and pressures. According to MassDEP, the standard acceptable pressure for drinking water transport is between 40 and 60 pounds per square inch (Gates, 2015). Regulating pressure allows for the pipes to have adequate flow so water can be readily accessible. These pressures also relate to the velocity of the water in the system; a range of velocities that are standard according to MassDEP are between two and eight feet per second. The velocity of the water, along with the pressure of the system, are directly related to the diameter of the pipes. In the TVSR system, pipe diameters range from three quarters of an inch to two inches.

4.1.2 Pumps

Three of the four wells at Treasure Valley deliver water at constant pressure throughout the Reservation. The pressure is maintained between 40 and 60 PSI by a number of hydro pneumatic tanks that hold the water being pumped before usage.

Farmhouse Well, which has the highest use of the pumps, is drilled to a depth of 110 feet and employs a 0.75-horsepower electric pump. This water is then pumped through a flow meter to two hydro pneumatic tanks. In 2014, the measured pumping rate was 3,229 GPD. To treat a coliform issue, a sodium hypochlorite feed system with a 30 gallon tank and LMI chemical pump is used by TVSR when bacteria levels exceed those allowed by MassDEP.

East Lodge Well, a seasonally operated well, is drilled to a depth of 230 feet and uses a 0.75-horsepower constant pressure electric submersible pump that changes its output in order maintain a constant pressure in the system, despite demand. This water is then pumped into a 90-gallon hydro pneumatic tank to provide pressure head for distribution. In 2014, the DEP recorded pumping rate was 1,921 GPD.

West Camp Well, which has the lowest operational output of the wells, is drilled to a depth of 135 feet and uses a one-horsepower electric submersible pump. The water is then pumped into five hydro pneumatic tanks after it has been filtered by the sediment filter. In 2014, the recorded DEP pumping rate was 781 GPD.

Boonesville Well is currently not in operation, but is drilled to a depth of 140 feet and is powered by a one-horsepower electric submersible pump. There are no hydro pneumatic pumps used by this well since the well is not currently in use (Gates, 2015).

These wells were supplemented by an above ground storage tank in West Camp of TVSR with a capacity of 3,000 gallons. This tank was installed by helicopter to serve as a backup and

main hydro pneumatic pressure source for the West Camp PVC pipe system. This tank is open to the atmosphere and currently not in operation. This tank would need to be cleaned and treated before re-instatement to the system, but it does not have any major operational issues. If this tank were to be needed at a different location within camp, extraction procedures would be extensive and would require airlift procedures (Howland Engineering Inc., 1988).

4.1.3 Depth to Water Table

Measurements of the existing wells and water table were obtained during field visits to TVSR. The depth to water for each well is located in Table 3. This data was translated into a profile view to create a visual representation of the water table of TVSR, represented in Figure 12. Any proposed well will have to meet or exceed this approximate depth to access the water table.

Table 3: Depth to water for each well of TVSR	
Well	Depth to Water (ft)
Farmhouse	14.8
West Lodge	12.2
East Lodge	38.4
Boonesville	3.4

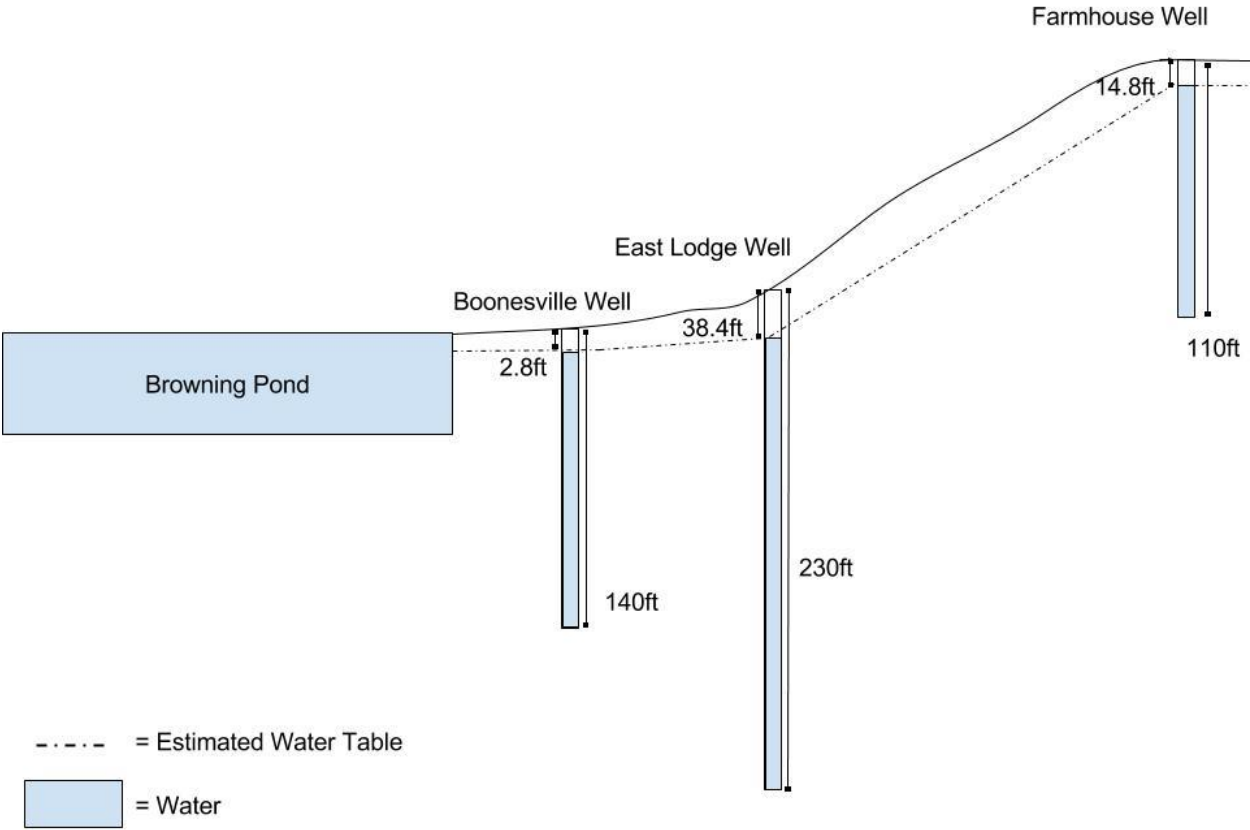


Figure 12: The estimated water table of TVSR. Note: this photo is not to scale

In addition to the depth to water measurements, the flow rate of a spigot at the Farmhouse well was measured. The project team was only able to acquire access to one spigot from the Farmhouse Well, as the rest of TVSR's wells had been shut down for the winter. The project team used a five-gallon bucket and recorded the amount of time it took to fill four gallons in the bucket. The results of this can be found in Table 4.

Table 4: Flow Rate of Farmhouse Well		
Trial #	Time to fill 4 gallons (seconds)	Flow Rate (gpm)
1	48.13	4.99
2	48.03	5.00
3	48.15	4.98
Average	48.10	4.99

Iron concentrations in milligrams per liter have increased at the Farmhouse well from 0.00 mg/L in 2012 to 0.50 mg/L in 2015 (Gates, 2015). Per Massachusetts law, if iron or manganese concentrations in raw water exceed 1.0 mg/L, contaminant removal is required to maintain safe drinking water standards. DEP, in their August 28th report, suggested that TVSR consider installing a treatment system to reduce these high concentrations of iron. Potential corrosion and degradation of existing piping and wells is suspected to be a possible cause of high iron samples at the Farmhouse Well.

4.1.4 Detailed System Inventory

To assist the project team, as well as provide a useful deliverable to TVSR, multiple GIS maps were generated. Within these maps, data pertaining to the water infrastructure was displayed in a way that allows for meaningful conclusions regarding the current condition of TVSR's water system. As seen previously in Figure 3, the visual representation of the camp includes roads, pipes, wells, campsites, and existing buildings.

Within the GIS generated map, there are layers that link components to different attributes that can be useful to the viewer. As seen in Figure 13, each of the pipes are identified by diameter as well as being classified as above or underground status. GIS allows the user to sum the lengths of different pipe sizes, which was used to determine total pipe costs of the water system.

When conducting the inventory of the system, the project team documented all valves, breaks, and splits in the existing pipe network. This information is important because someone making repairs or performing maintenance to the system will be able to easily identify important areas. Pictures of these components were compiled and matched to corresponding coordinates via HTML links. As seen in Figure 14, the shutoff valve location and photo provides a means to address system issues in an expedient way.

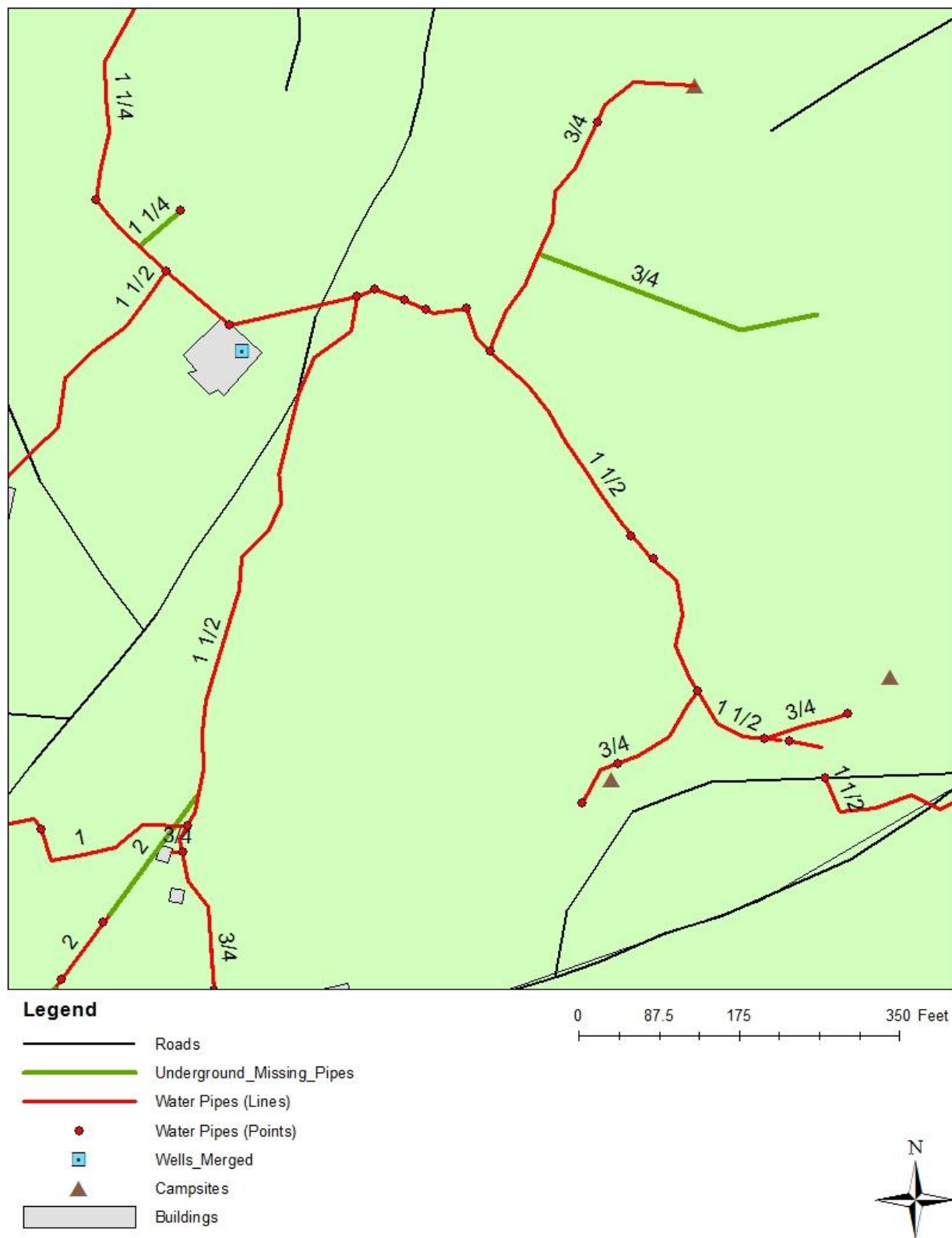


Figure 13: A close up view of the project team's GIS files, displaying pipe diameter and location at TVSR



Figure 14: An example of the embedded photos in the project team's GIS files (GIS, 2016)

A further explanation of GIS data can be found in Appendix G, “How to Use QGIS”.

This guide provides instruction on how to view the data layers prepared by the project team, and presents usable information for TVSR maintenance purposes.

4.2 Current Water Demand

The effectiveness of the current water infrastructure is dependent on whether it is able to meet the demands of the camp. The leaders of TVSR have stated that the current system can meet the requirements of the campers that currently attend. The true test of the system effectiveness is whether the system can meet the demands of the camp filled to maximum human capacity. In the interest of meeting a rise in attendance, it was necessary to calculate the amount of water the Reservation would require if all buildings and campsites were occupied.

The maximum amount of water the Reservation will need if the camp is filled to capacity is largely dependent on the amount of water each camper uses per day. The average water usage per person was calculated based on average water usage per day of an average camper as determined by the American Water Works Association. Camper activities requiring water were taken into account for total average daily water usage. These activities, their corresponding average water usage, and the total average water use per day of an average camper are shown in Table 5.

Table 5: Average values for typical water features (American Water Works Association, 2008)

Type of Use	Average gallons per day (GPD)
Toilet	18.5
Shower	11.6
Faucet	10.9
Other domestic	1.6
Leakage	9.5
Total	52.1

It was necessary for the project team to determine the number of people that can be housed in the reservation at any point to determine the maximum water demand and camper capacity. Assuming the entire camp is full, the water system should be able to sustain the amount of people housed. The amount of people the camp could theoretically support was determined through the TVSR website which lists how many campers and adults each building can support. These data were collected and are summarized in Table 6. These data were then multiplied by the amount of water an average person uses to determine the maximum water demand for each building. This was added together to create the maximum water demand of all the buildings and is displayed in the final column of Table 6.

Table 6: Maximum water demand of TVSR buildings					
Building	Building Location	Human Capacity (# of people)	Hot Water	Type	Max Water Demand (gpd)
Adirondack	East	48	none	Overnight	2500
Coghlin	East	0	year round		0
Columbus	West	0	none	Day	0
Directors Cottage	East	5	seasonal	Overnight	260
Eagle Lodge	East	26	none	Overnight	1350
King Cottage	East	2	year round	Overnight	104
Magee Center	East	1	year round	Day	52
Probus	East	10	none	Overnight	520
Ranger farmhouse complex	East	5	year round	Day	260
Venture Lodge	West	28	no	Overnight	1460
West Lodge	West	22	no	Overnight	1150
Total		147			7656

The number of people that can occupy each campsite is also an important factor when calculating the maximum water demand. The project team gathered information on how many campers and adults can stay at each campsite and organized this information in Table 7. The method used to determine the maximum water demand for the buildings of TVSR was replicated to determine the maximum campsite water demands.

Table 7: Camper capacity of all campsites, active and inactive, at TVSR (Mohegan Council, 2015).

Campsite	Campsite Location	Human Capacity (# of people)	Hot Water	Max Water Demand (gpd)
Arrow	East	0	none	0
Baden Powell	East	25	none	1300
Brownsea	West	0	none	0
Chippewa	East	37	none	1930
Deer Trail	West	0	none	0
Evergreen	East	42	seasonal	2190
Ft Courage	West	0	none	0
Hardwood	West	0	none	0
Hemlocks	East	50	seasonal	2610
Hickory	East	40	none	2080
High Mesa	East	48	seasonal	2500
Katahdin	West	0	none	0
Kodiak	West	0	none	0
Madore	East	38	seasonal	1980
Pine Acres	East	48	seasonal	2500
Poctor	East	0	none	0
Rocky Point	West	0	none	0
Sleepy Hollow	East	42	none	2190
Tall Maples	East	27	none	1410
Thunderbird	East	46	seasonal	2400
Trail's End	West	0	none	0
Whispering Hill	West	0	none	0
Total Campers		443		23,090

Summing the totals from Table 6 and 7 resulted in the determination that the Reservation will have to pump approximately 31,000 gallons of water from East and West Camp combined per day if operating at maximum camper capacity. At current camper attendance, TVSR pumps approximately 18% of this future demand, based on 2014 pumping estimates from MassDEP, discussed in detail in Section 4.3.1. TVSR, therefore, is limited by the allowable pumping rate of

5,797 gallons established by MassDEP, regardless of their theoretical maximum pumping demand. Due to regulatory guidelines discussed further in Section 4.3, related to groundwater recharge and the general health of water resources, the theoretical maximum demand of 31,000 gallons may not be achievable given the existing water resources of the Reservation.

4.3 Design Constraints

Design constraints are important factors in engineering. The project team identified those applicable to the water system of TVSR. The primary constraints that effect the design and implementation of the project team's recommendations are regulatory. Massachusetts DEP sets standards regarding water quality, waste management, and zoning distances that directly relate to the project. Each of these regulatory sections specify which of the laws are applicable to the water system.

4.3.1 Water Quality Regulations

Massachusetts Drinking Water Regulations, intended to promote public health and welfare, are designed to prevent the pollution of drinking water sources. All water distribution and sanitation systems are covered by these regulations, and ensure that water delivered to residents of the Commonwealth of Massachusetts consume "is safe, fit and pure to drink" (310 CMR 22.00, 2009).

As the primary protector of drinking water in Massachusetts, MassDEP conducts periodic Sanitary Surveys pursuant to section 22.04(12), which allows MassDEP to "evaluate system's source, facilities, equipment...and maintenance procedures" as determined by MassDEP (310 CMR 22.00, 2009). During this sanitary survey, MassDEP tests alarms, chemical feeders, flowrates, and the general health of a public water systems well according to Chapter six of the

Guidelines for Public Water Systems (MassDEP, 2016b). Necessary grab samples are required on a monthly basis by MassDEP to measure total coliform and other pathogens (CMR 22.05 (1), 2009).

310 CMR 22.00 is the section of Massachusetts General Law which pertains to drinking water standards. These regulations cover the expansion of public water systems (22.04), approved pumping rates (22.21), and relevant legal and safety information for all wells (310 CMR 22.11 B (5) (b), 310 CMR 22.11B(1), 310 CMR 22.04 (f)). This information is used by MassDEP, contractors, and TVSR to ensure the proper running of the water distribution system. Any substantial changes or modifications to TVSR's water system would have to comply with the entirety of 310 CMR 22.00, unless prior approval through waivers are applied for and approved by MassDEP.

All water use for wells must be accounted for in the Annual Statistical Report. TVSR is required to report the results of every test, measurement, or analysis. The supplier of water is required to report findings by 310 CMR 22.00 within the first ten days following the month results are received or the first ten days following the end of the required monitoring period as ordered by MassDEP. MassDEP also requires monthly reports recording the use of chemicals added to the water supply. These reports must include the name of the chemical, the amount added, the resulting concentration of the chemical in water, and the reason for adding the chemical to the water.

Protective radii for wellheads are established and enforced at all drinking water wells in Massachusetts. There are two radii that presently pertain to TVSR. Zone I Radii, which is the protective radius required around a public water supply well (310 CMR 22.02, 2009). The second radius is an Interim Wellhead Protection Area (IWPA), which is applied by MassDEP standards

when a Zone II radius is not present (310 CMR 22.02, 2009). The Zone I and IWPA radii for the East Lodge Well and the Farmhouse Well are illustrated in Figure 15 and Figure 16, respectively.

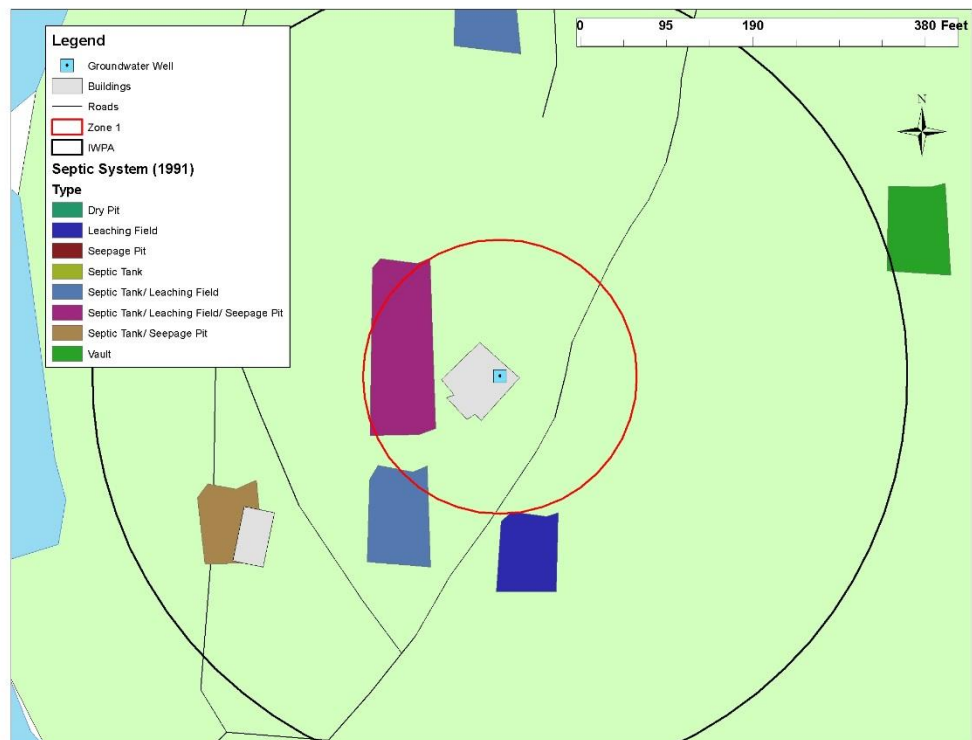


Figure 15: The Zone I and IWPA radius around the East Lodge Well

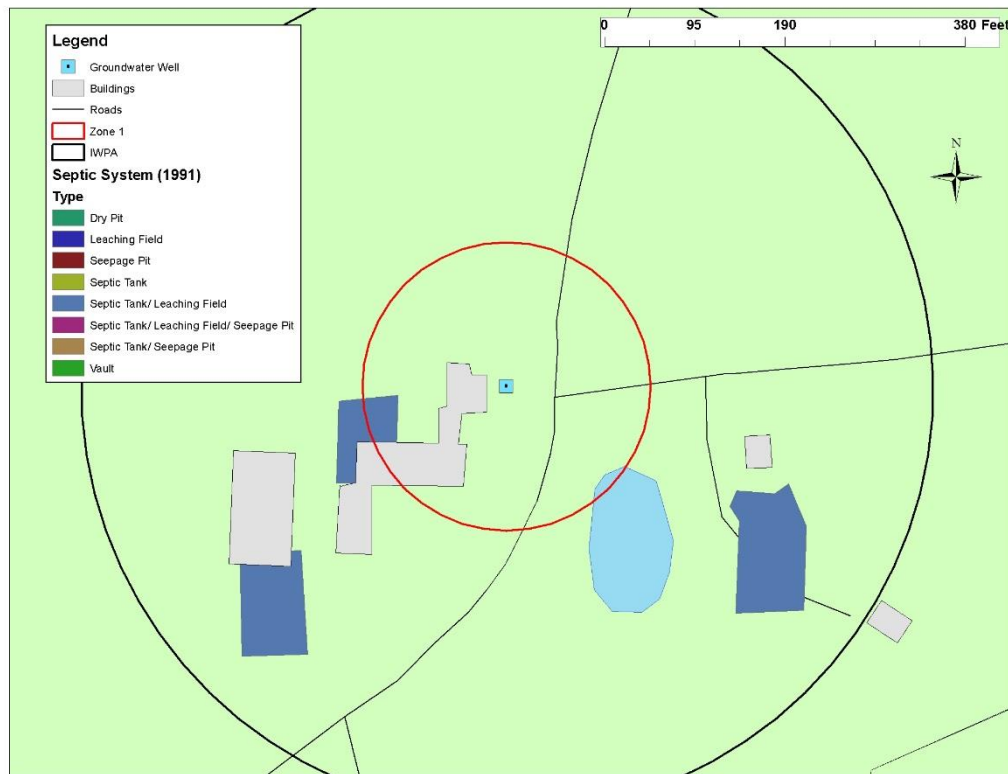


Figure 16: The Zone I and IWPA radii around the Farmhouse Well

Zone I radii, illustrated with the red circles around each well, represents an approximate area with a radius of around 153 feet; this value is representative of the zone one radii of wells with the largest pull. Only activities which “will have no adverse impact on water quality” are permitted within that zone (MassDEP, 2009b).

As previously shown in Figure 15 and Figure 16, there are active leaching fields and septic tanks in that protected area. The presence of these sewage systems represents a potential source of contamination for total coliform and other harmful pathogens to TVSR’s water supply.

The larger, black circles in Figure 15 and Figure 16 represent the Interim Wellhead Protection Areas, which encompass the estimated withdrawal areas for groundwater wells under the most extreme circumstances (310 CMR 22.02, 2009). As is evident in the figures, the IWPA radius is much larger. Although the area contains more potential contamination risks, their usage is allowed per MassDEP.

Zone I regulations mandate that all land included in the Zone I radii be owned by the supplier of the water, and that land uses inside the radius have “no significant impact on water quality” (310 CMR 22.21 (3)(b), 2009). The Zone I equations for TVSR, completed by MassDEP, were reversed in order to determine the gallons per day usage for each well. From the Zone I equation (below), the project team determined that, on an average operational day, TVSR is restricted to pumping 2,238 gallons from the Farmhouse Well, 2,221 gallons from East Lodge Well, 1,338 gallons from West Camp Well, and a hypothetical 1,000 gallons per day from the currently decommissioned Boonesville Well. This information is displayed in Table 8. To remain compliant with Zone I radii, TVSR is limited to pumping 5,981 gallons per day from the three operational wells.

$$\text{Zone I radius in feet} = (150 \times \log \text{ of pumping rate in gpd}) - 350$$

Table 8: Measured and Allowable Pumping Rates (Gates, 2015)		
Well	2014 Pumping Rate (GPD)	Allowable Pumping rate (GPD)
West	781	1,338
East	1,921	2,221
Farmhouse	3,229	2,238
Total	5,931	5,797

The IWPA radius is applied to wells which do not have a MassDEP approved Zone II radius, and is applied to transient non-community wells when there is no metered rate of withdrawal or approved pumping rate (310 CMR 22.02). IWPA radii are designed to protect the contributing area of a groundwater well from potential contaminants. The interim wellhead protection area is determined through calculations using the “most severe pumping and recharge conditions that can be realistically anticipated” and is proportional to the approved pumping rate (310 CMR 22.02). The project team used the IWPA radii given by MassDEP in their August 27th report to determine the assumed gallons of water per minute pumped at each well, shown in Table 9.

Table 9: Radii and flowrates for each well (Gates, 2015)				
Location	Zone I Radius (ft)	IWPA Radius (ft)	GPM	GPD
Farmhouse	153	450	1.6	2238
East	152	449	1.5	2221
West	119	430	0.9	1338
Boonesville	100	500	0.7	1000

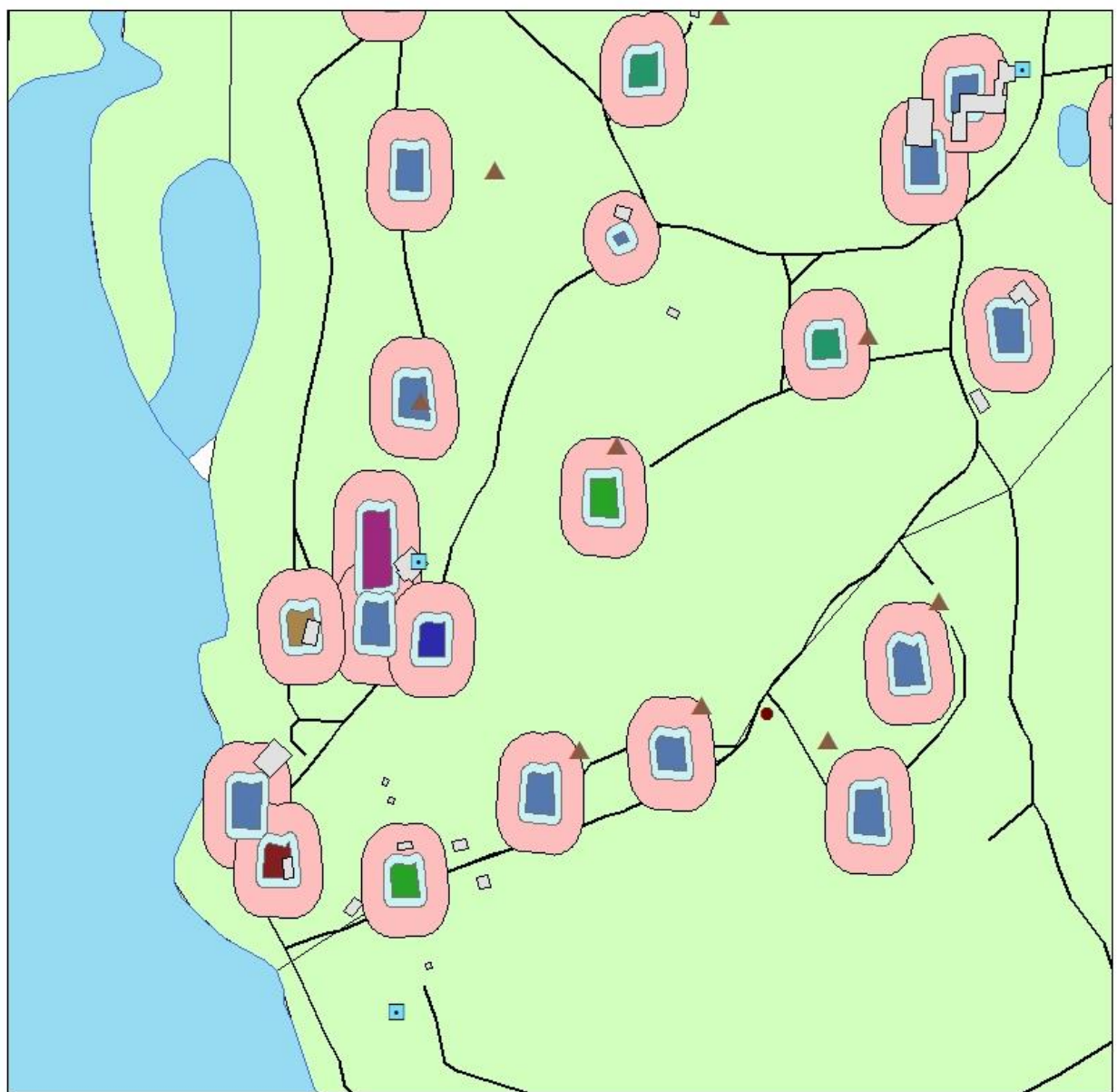
According to the regulatory restrictions on well-water pumping at TVSR, the current water distribution system would not be able to sustain the maximum theoretical pumping capacity of 31,000 GPD. At the current state, the GPD capacity restricted by MassDEP is less than 7,000 GPD assuming that all of the wells are being pumped to maximum capacity.

4.3.2 Septic System Regulations

According to CMR 15.029: Construction of Wells Near Existing Systems, it is a violation to construct or install a water supply well closer to a system component than the relevant setbacks in 310 CMR 15.211 (310 CMR 15.211, 2009). This means, in the case of existing water supplies

installed prior to the issuance of these regulations, that their current locations are allowable. In the case of new well installation, however, the water supply wells must abide by CMR 15.029.

Any new septic field must be accompanied by a hydrogeological study of the surrounding area pursuant to 310 CMR 15.107. This study identifies where the water flows in relation to existing ground water sources and the proposed septic field. Within the proposed area of influence for a septic field, if more than one setback is applicable in the area, then all lesser setback requirements shall also be satisfied (310 CMR 15.211, 2009). The buffers in Figure 17 represent the required set back distance around all identified vaults, septic and leach fields. This information was gathered from a hand drawn map of the camp from 1991.



0 237.5 475 950 Feet

Legend



-  Roads
-  Wells_Merged
-  Campsites
-  Buildings
-  Septic_System_Buffer_property_lines_10ft
-  Septic_System_Buffer_water_supply_line_10ft
-  Septic_System_Buffer_surface_waters_25ft
-  Septic_System_Buffer_other_septic_100ft



Figure 17: The buffers around septic fields, shown in accordance with regulations prescribed by MassDEP

4.3.3 Applicable Buffer Distances

The water quality and septic systems regulations summarized in the previous two sections include variety of buffer distances that need to be considered in the design and evaluation of water distribution systems. First, Title V regulations as dictated by MassDEP specify buffer zones around septic systems for which drinking water wells cannot reside. These buffers were added to each of the septic systems as seen in Figure 18. Adding these buffers from Table 10 into one layer yielded the anti-buffer layer. This anti-buffer layer, coupled with the buffers around the existing wells, highlighted all suitable areas that a new well could be located. The well buffers were included with the buffer layer to avoid drilling near existing groundwater wells to diversify the water supply. This map served the dual purpose of reinforcing the fact that some of the existing wells lie within areas not appropriate for well locations.

The installation of new wells requires adherence with all MassDEP guidelines and local boards of health. Relevant buffer distances, applicable to TVSR's operation and possible relocation of ground water wells, are included in Table 10. These buffers are the most stringent limitations on the placement of new wells, as the uncertainty associated with knowing which septic and leaching fields are operational may hinder new well sites at TVSR. It is important to note that these buffer distances are the minimum required by MassDEP; in some instances it may be more prudent to extend the buffer distance to provide space for future expansion or renovation of existing facilities. The cost of material and labor associated with modifications is discussed in Section 4.4 of this report.

Table 10: Relevant setback distances for groundwater wells in Massachusetts		
Applicable Regulations		
	Setback Distance (ft)	Applicable Regulation
Potential Contamination Sources	200	Private Well Guidelines, page 14
Property Lines	10	Private Well Guidelines, page 14
Gas lines	15	Private Well Guidelines, page 14
Power Lines	25	Private Well Guidelines, page 14
Surface Water (high water mark)	25	Private Well Guidelines, page 15
Wetlands	100	Ch. 131, Section 40, MGL 310 CMR 10.00
Septic Tank	50	Ch. 21, Section 13, MGL 310 CMR 15.00
Leaching Facility	100	Ch. 21, Section 13, MGL 310 CMR 15.00
Outhouse/Privy	100	Ch. 21, Section 13, MGL, and 310 CMR 15.00
Roads	25	Private Well Guidelines, page 14
Right of Way	15	Private Well Guidelines, page 14

Figure 18 shows the layers of data applicable to the TVSR water system. There are two major zones defined in this image: buildable zones and unbuildable zones. Unbuildable zones are areas where it is not legally feasible to establish a new well; it is a combination of buffers on features regulated by MassDEP. Buffers in this layer exist on septic systems, buildings, roads, bodies of water, and parking lots. This information was useful to the project group in finding new locations for drinking water wells and will serve as a useful tool for TVSR in future camp development.

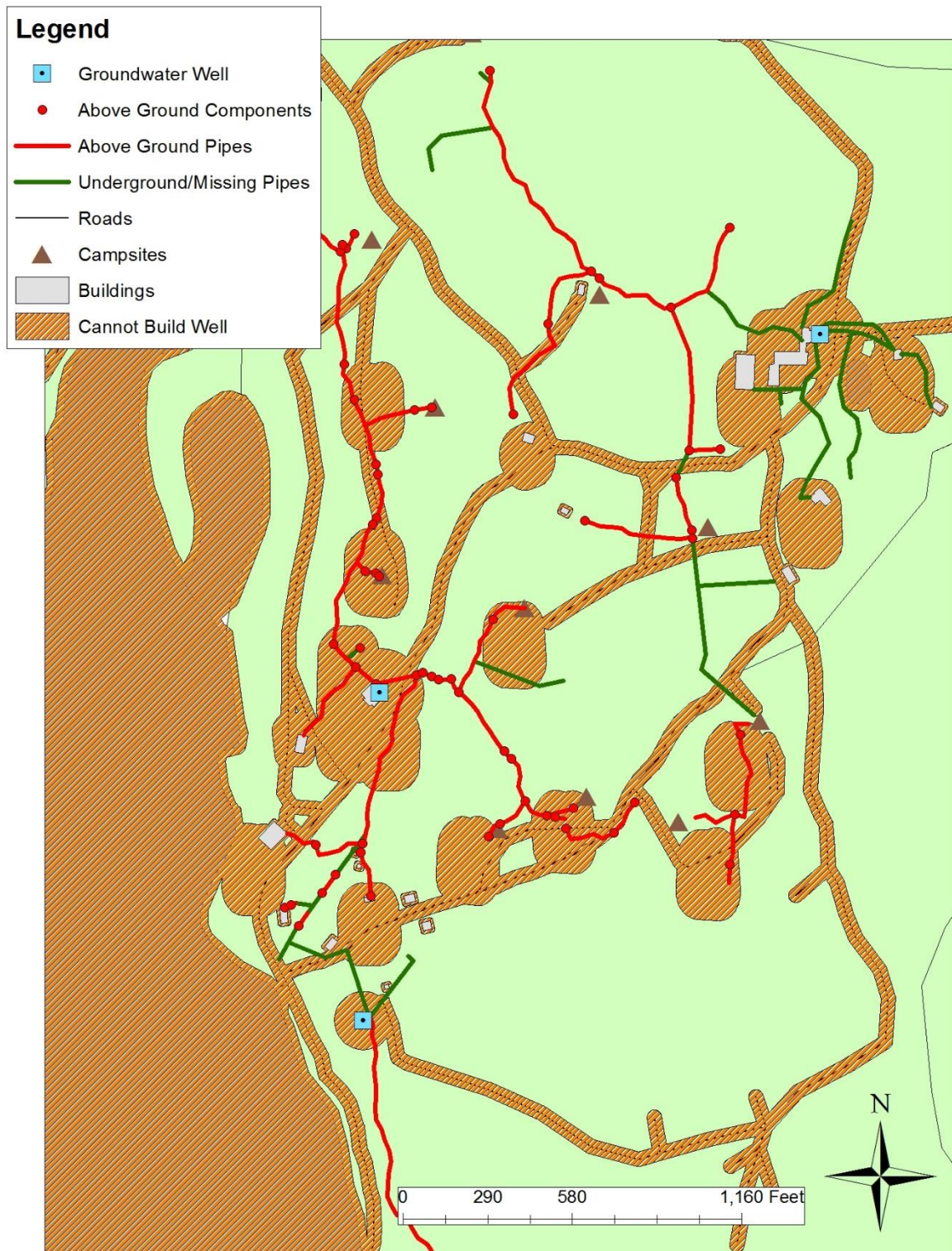


Figure 18: Map of the permissible well drilling areas based on contaminant buffers .

4.4 Cost of Labor and Materials

One of the objectives of the project was to generate design alternatives to the existing pipe network. Thus, it became necessary to investigate different pipe materials. Several types of materials were considered, such as polyethylene and PVC. To achieve a comprehensive cost analysis of replacing the pipe network, associated costs of labor and construction time were researched for each pipe material. The stakeholders of TVSR expressed a desire for year round water access, which prompted the project team to investigate possible solutions. The project team investigated winterizing the system by means of trenching or insulation. The cost of labor and materials associated with winterization were determined to accomplish this task. This section includes material and labor costs for pipe materials, components, insulation materials, and trenching.

4.4.1 Pipe Material, Labor, and Cost

Material cost was a primary factor in the determination of the best material to replace the current pipe infrastructure. Vendors, including Lowe's and Home Depot, were used to determine costs of some of these materials. These vendor prices were compared to RSMeans, a reference catalog for plumbing supplies. Unit costs were used to develop a total estimated price, displayed in Table 11. Refer to Table 1 to find the lengths of pipe that were used in this calculation.

Table 11: Total Material cost associated with pipe replacement (Babbitt et al., 2011; Homer TLC Inc, 2016; LF LLC, 2016; W.W. Grainger Inc, 2016)				
Material	Source	Above Ground (AG)	Below Ground (BG)	TOTAL
Galvanized Steel	Home Depot	\$29,900	\$16,300	\$46,200
PVC	Lowe's	\$5,400	\$3,200	\$8,600
	RSMeans	\$3,200	\$1,900	\$5,100
Polyethylene	Home Depot	\$4,000	\$2,300	\$6,300
	RSMeans	\$9,000	\$5,400	\$14,400
Chlorinated polyvinylchloride	Grainger	\$54,000	\$31,000	\$85,000

Another major factor in determining a new material to replace the current pipe network was the amount of time and cost of installation. Often times, the labor costs can be more substantial than the material itself and would therefore be a determining factor when considering modifications. The time it takes to install pipes of specific diameters were determined by R.S. Means (Babbitt et al., 2011). The amount of time and associated labor costs were found per foot of pipe as well. This was then multiplied by the total amount of pipe to find the total time and cost of installation. A table of this calculation can be found in Appendix E. The total cost to replace the entire system with each material is shown Table 12.

Table 12: Labor hours and cost (Babbitt et al., 2011)

	Above Ground Hours	Above Ground Cost	Below Ground Hours	Below Ground Cost	Total Hours	Total Cost
Galvanized Steel	1870	\$114,000	1020	\$61,000	2890	\$175,000
PVC	720	\$7,000	340	\$4,000	1,060	\$11,000
Polyethylene	240	\$13,000	130	\$7,000	370	\$20,000

4.4.2 Component Material, Labor, and Cost

Additional aspects of the water infrastructure that were considered were the components that connect the system, this included three-way connectors and shut-off valves. The total inventory of all the components in the system can be found in Table 13. Cost estimates were generated using Home Depot, Lowe's and RSMeans. To create a complete cost estimate, the amount of each component in East Camp were separated by size. The number of different components can be found in Table 13.

Table 13: Components Inventory of East Camp

	3/4"	1"	1 1/4"	1 1/2"	2"
Three-Way Connectors	12	2	5	10	2
Shut-Off Valves	5	2	1	3	0
Connectors	4	0	2	4	1

Price estimates were generated after sorting each component. The price per component was multiplied by the number of components of that size category and the total cost of all components are displayed in Table 14.

Table 14: Total Price of Component pieces (Babbitt et al., 2011; Homer TLC Inc, 2016; LF LLC, 2016)				
Type	Material	Source	Date	TOTAL
Three-Way Connectors	PVC	Home Depot	1/25/2016	\$90
	PVC	RSMeans	1/28/2016	\$330
	Iron	Home Depot	1/25/2016	\$250
Shut-Off Valves	PVC	grainger.com	1/25/2016	\$870
Connectors	Galvanized Steel	Home Depot	1/25/2016	\$170
	PVC	Home Depot	1/25/2016	\$60
	PVC	RSMeans	1/28/2016	\$60
	Polyethylene	RSMeans	1/28/2016	\$20

Using the RSMeans 2011 Plumbing Catalog, the amount of time to install the components of different materials was determined. RSMeans provided the installation times for each of these components. This value was then multiplied to give the total labor cost and as shown in Table 15. Unit labor cost was multiplied by the number of components and is also shown in Table 15.

Table 15: Summation of labor costs based on estimated hours of work (Babbitt et al., 2011)		
	Total Hours	Total Cost
Three-Way Connectors - PVC	5	\$270
Connectors - PVC	1.2	\$60
Connectors - Polyethylene	2	\$110

4.4.3 Insulation Material, Labor, and Cost

The project team investigated the possibility of insulating the pipes in the system with different materials so TVSR would have more water access in the cold winter months. The two main insulating materials investigated were foam and rubber insulation. The cost and R-values of the insulation material were investigated. The R-value of an insulating material refers to the material's ability to resist the flow of heat. The R-value for the foam insulation is 3.1 while the R-value for the rubber insulation is 3.3. A higher R-value indicates that the material has a greater insulating capacity. Unit costs were used to determine the associated costs to insulate and are found in Table 16.

Table 16: Total cost of insulation of above ground pipes in East Camp (Babbitt et al., 2011; Homer TLC Inc, 2016)		
Material	Source	TOTAL
Foam Insulation	Home Depot	\$9,500
Rubber Insulation	Home Depot	\$17,600
Rubber Insulation	RS Means	\$9,600

Labor costs were necessary to calculate for insulating and burying the pipes in the ground, as well as the labor hours required for installation. Information on rubber insulation was the only data that could be found for this analysis. The amount of time required to insulate pipes of different diameters were then multiplied by the total distance of pipe in Table 2. The results of this calculation can be found in Table 17.

Table 17: Labor Hours and Costs Required to Insulate with Rubber (Babbitt et al., 2011)						
	3/4"	1"	1 1/4"	1 1/2"	2"	Total
Total Hours	460	60	130	190	20	860
Total Costs	\$21,300	\$2,700	\$6,100	\$9,000	\$700	\$39,800

4.4.4 Trenching Labor and Cost

There are general guidelines that should be followed when trenching water distribution networks. The first step would be to establish the desired location of the winterized pipe system. The depth of the trench should be below the established frost line which was assumed to be greater than four feet for this area. The width of the trench should be equal to the diameter of the pipe plus another foot. The bottom of the trench should be free of rocks and other obstructions.

Most pipes made from plastic components like PVC and CPVC can be placed by hand due to their weight while heavier materials like galvanized steel may require special equipment to lift. When filling in the trench, a majority of the soil should be coarse grained gravel or sand. The particle size should not exceed one-half inch and compacted to at least 85 percent Standard Proctor density (Plastics Pipe Institute, 2015). If the pipe is going to have roads going over it, the compaction should be 95 percent Standard Proctor density. The soil layer on the top, called the

final backfill, should contain soil from the excavated material provided it is free of obstructive hazards, such as boulders or organic matter (Plastics Pipe Institute, 2015).

The time required to trench the pipes, although extensive, can provide stability to a water infrastructure once the pipes are trenched. The only estimates that were obtained were for the labor hours associated with trenching PVC pipe. The estimates provided by RSMeans 2011 for trenching different diameters of PVC piping 3 feet deep were used to determine the values in Table 18. After the time of trenching was determined, it became necessary to calculate the costs associated with the total of pipes of each diameter as reported in Table 2. The results of the calculation can be found in Table 18.

Table 18: Total Labor Hours and Cost Required to Trench 3 feet (Babbitt et al., 2011)		
	Total Hours	Total Costs
PVC - including trenching to 3' deep	850	\$40,000

5.0 Design Alternatives

This sections details the solutions the project team has developed to address the current limitations associated with TVSR's water distribution system. Each of these options was designed to improve TVSR's water supply capacity, remediate existing problem areas, and/or expand water accessibility throughout TVSR. This section includes cost and labor estimates, as well possible locations for additions and relocations to the distribution system. These design alternatives are to:

1. Address contamination risk
2. Move wells
3. Replace infrastructure
4. Winterize
5. Maintain current well locations

These alternatives are detailed in the following subsections and are organized by pertinence to TVSR. Discussions are included on the threat of contaminations, relocation of the wells, replacement of current infrastructure, winterization of the system, as well as maintaining well locations. Each section includes cost and labor estimates as well as a general discussion of the selected alternatives.

5.1 Address Contamination

Contamination risks are increased in drinking water sources when there are septic systems or other potential contamination sources located within the well capture zones, which are normally designated by buffer zones. To reduce the future risk of total coliform and other pathogens contaminating the water supply of TVSR, a number of steps can be taken. The first suggestion in to shut down and relocate septic and leach fields within the Zone I radii of the Farmhouse and East Lodge Wells as seen in Figure 15 and Figure 16. Other options can be explored by other MQP

teams because this topic is outside the scope of the current project. This is recommended because the presence of these sewage disposal systems within the Zone I radii are potential sources of contamination for Total Coliform and other pathogens. Relocating each of the four leach fields in the Zone I radius of a well could cost between \$4,000-14,000, depending on the size of the system, labor, and material costs (Babbitt et al., 2011).

These contamination risks include total coliform and increasing iron and manganese levels. Closing leaching and septic fields within the Zone I radii of each well take time and the use of these wells would not stop while these fields are being shut down. The Chlorine drip system of Farmhouse would need to be employed during this process to handle biological contaminants. Installing a treatment method for iron and manganese on East Lodge Well is also necessary and would incur a low, long term operational costs in comparison to a large, one time capital cost to drill new wells. This option would not fully address the problems TVSR faces and would merely treat the symptoms of an inefficient system.

5.2 Relocation of Pumping Wells

Another alternative for improving the water infrastructure of TVSR would be the relocation of groundwater wells. Removing the well and placing the well away from possible contamination sites would reduce the risk of pathogens infecting the water distribution system. This was an important option to consider given the present deficiencies of the East Lodge and Farmhouse Wells.

The main source providing information on material and labor costs was Northeast Water Wells Inc. This company conducted a phone interview on February 2, 2016 with the team and provided several verbal quotes for the installation of a new drinking water well. In this

correspondence, Northeast Water Wells Inc. stated that new wells are drilled for approximately ten dollars a foot and eighteen dollars a foot for casings. All of TVSR's new wells would be drilled into bedrock and would incur an estimated cost of \$2,400 for each well. Cost estimates for the relocation and replication of each of the wells in new locations with similar conditions are presented in Table 19.

Table 19: Cost estimates for drilling new wells (Personal Communication, Northeast Waterwells Inc. 2016; (Babbitt et al., 2011)					
Well	Pump Cost (\$)	Casing Cost (\$)	Depth Cost (\$)	Drilling(\$)	Total (\$)
Farmhouse	970	450	1100	2400	4920
East	970	450	2300	2400	6120
West	1125	900	1350	2400	5775
Boonesville	1125	900	1400	2400	5825

A visual representation of possible relocations sites are displayed in Figure 19. Included in this figure are the IPWA and Zone I radii, as displayed in a GIS map created by the project team. All known GIS data for TVSR were combined and buffers were created around each restrictive feature to identify the areas of TVSR where new groundwater wells could not be placed. Acceptable areas for new groundwater wells were identified by placing the current Zone I and IWPA radii in areas of TVSR that are not obstructed by the buffer layers. If the Zone I circle did not overlap with sources of contamination, then that area was considered to be adequate for new wells.

These areas were chosen based on their maximum distance from potential sources of contamination. The buffers for each of these sources were included in Figure 19 to identify locations where smaller producing wells, with smaller Zone I and IWPA radii, could possibly be placed if TVSR decided to downsize the amount of water pumped from each well. The pumping

rates were determined by using the existing three wells of TVSR. These rates may change based on DEP requirements and the future water demands of TVSR, and would alter the IWPA and Zone I radii respectively. These locations offer TVSR the opportunity to easily expand a portion of their system to accommodate new wells. In light of these potential new well locations, the following options were considered:

1. Move East Lodge well
2. Move Farmhouse well
3. Do not move any wells (Section 5.5)

The considerations and costs associated with these options are included in the following subsections.

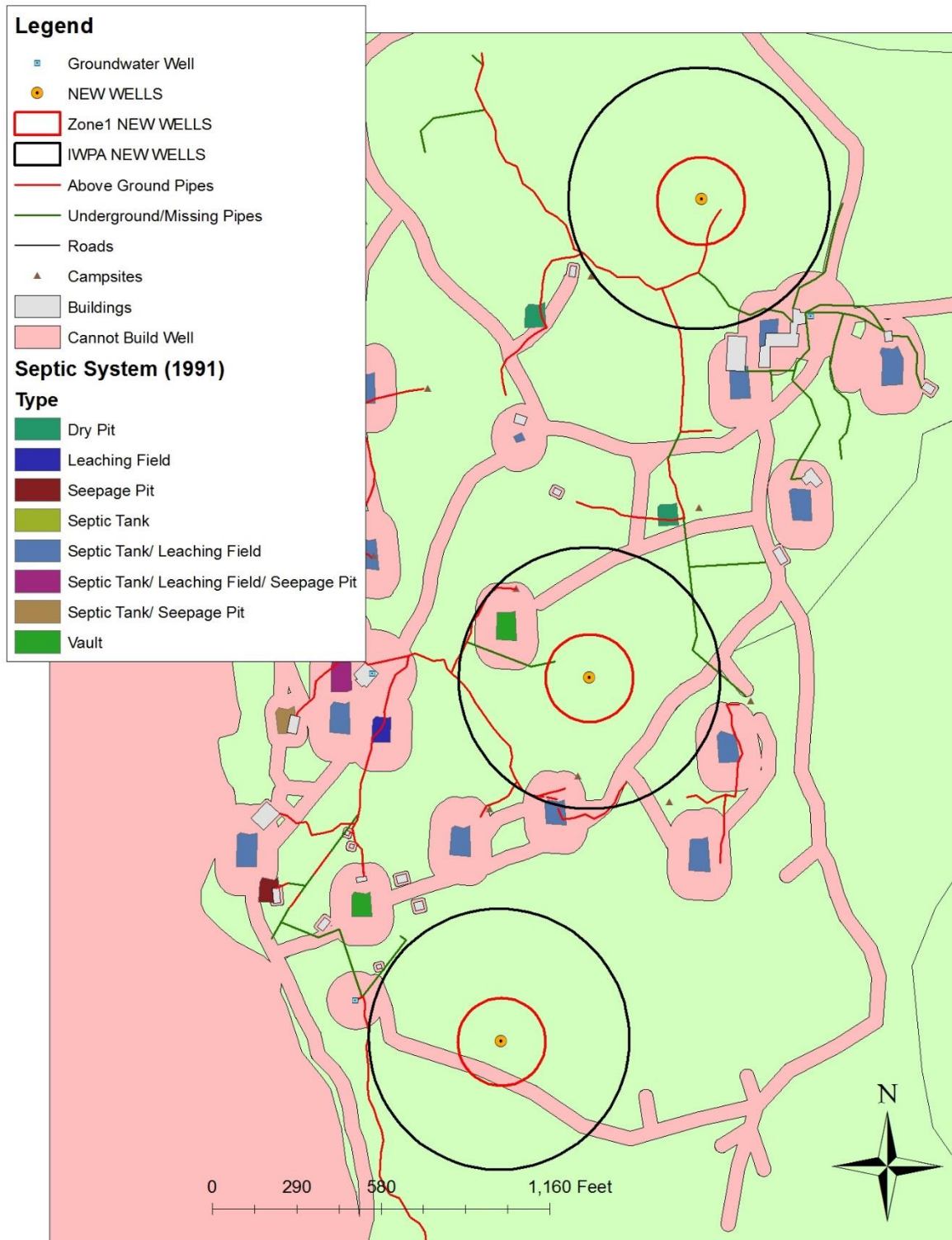


Figure 19: Possible new well locations as determined by Zone I and IWPA radii (Project Team, 2016)

5.2.1 Move East Lodge Well

The project team assessed the monetary investment required to re-establish the East Lodge Well in a separate location. Relocating the East Lodge Well was a major concern because the well is currently located directly underneath East Lodge. The East Lodge Well has exhibited problems with iron staining, as evidenced by the stains in the showers serviced by this well. Possible new locations for the East Lodge Well are displayed in Figure 19. Costs associated with this proposal are shown in **Table 20**. In Table 19, it is shown that the East Lodge Well would be the most expensive to replicate, due to the depth of the well; at 230 feet deep, it is the deepest of the wells at TVSR. Replication of this well may ultimately not be necessary due to varying depths of the water table at TVSR. The total cost to replicate a well similar to the East Lodge Well would be approximately \$6,200. This cost estimate includes the costs associated with connecting a new well to the system.

Table 20: Associated costs for potential new well locations		
	New Piping Length (feet)	New Pipe and Labor Cost (total cost \$)
East Lodge Well	100-500	70-360
Farmhouse Well	50-100	30-70

5.2.2 Move Farmhouse Well

Relocating the Farmhouse well to one of the locations identified in Figure 19 is highly recommended, as it is the most important well in the TVSR system. This well has been treated for bacteria in the past with a chlorine drip system, and an alternative solution to chemical treatment would be well relocation. The project team, after completing a site analysis of the area surrounding the well, suspects that the contamination may be due to a leaching field located within the Zone I radius of the well. The total cost of moving the Farmhouse well is the least expensive of the wells given that it is the shallowest. Associated costs of new piping and labor costs are approximately

30-70 dollars as shown in **Table 20**. The winterized pipe network branching from the existing Farmhouse Well would not be difficult to extend based on its close proximity to the existing network. The total cost to replicate the Farmhouse well in a new location would be approximately \$5,500.

5.3 Replace Distribution Infrastructure

To improve the water infrastructure of TVSR, another alternative would be to completely replace the water distribution infrastructure. This alternative stems from the team's experience with the TVSR pipe network and the uncertainty surrounding the durability of certain aspects of the system. If TVSR wishes to winterize their network to expand operational capabilities, replacing the pipe network for each well with a more durable material and placement method could be an option.

Cost estimates, found in Section 4.4, were generated for each piping material. In terms of total costs, CPVC was the most expensive, followed by galvanized steel. In terms of cost effectiveness, PVC and PE were the most affordable. In terms of practicality, steel is the hardest to work with but also is the sturdiest. CPVC and PVC are less sturdy and durable, but are lighter and easier to work with. Using a plastic material like CPVC, PVC, or Polyethylene provides the advantage of being resistant to corrosion, especially if chlorine is being used in treatment. Steel will corrode when chlorine is used as a disinfectant and can leave unwanted byproducts in the water.

The most logical material to replace the current system is PVC. It is one of the most widely used materials in piping and balances cost efficiency with ease of installation. The only negative aspect of PVC is its lack of durability, which would need to be addressed. The summation of the material cost of replacing the current system with PVC is shown in Table 21.

A new network design as seen in Figure 20: New pipe network of East Camp (Project Team, 2016)Figure 20 will contain only 3/4-inch diameter piping. With a flowrate of five gallons per minute, the velocities will be less than 3.6 feet per second water and the length of pipe will be 80 percent less than the existing network pipe length. These pipe length and water velocity calculations are as follows.

$$\text{pipe length reduction percent} = \frac{(\text{existing pipe length} - \text{new pipe length design length})}{\text{existing pipe length}} * 100$$

$$V = \frac{Q}{A}$$

$$Q = 5 \frac{\text{gal}}{\text{min}} = 0.011 \text{ ft}^3/\text{sec}$$

$$A = 0.003 \text{ ft}^2$$

$$V = \frac{0.011 \text{ ft}^3/\text{sec}}{0.003 \text{ ft}^2} = 3.6 \text{ ft/s}$$

It is recommended that while laying this pipe, that the pipe be placed underground in trenches to provide a year round water supply. This will cost approximately \$16,000 to purchase, trench, and place the new pipe.

Table 21: Material and labor costs for PVC (Babbitt et al., 2011)			
	Material Cost (\$)	Labor Hours	Labor Cost (\$)
Above Ground Pipe Replacement (R.S. Means)	3,200	720	7200
Below Ground Pipe Replacement (R.S. Means)	1,900	340	3800
Total Component Replacement (Home Depot, grainger.com, R.S. Means)	1,000	8	440
Total	\$6,100	1068	\$11,440

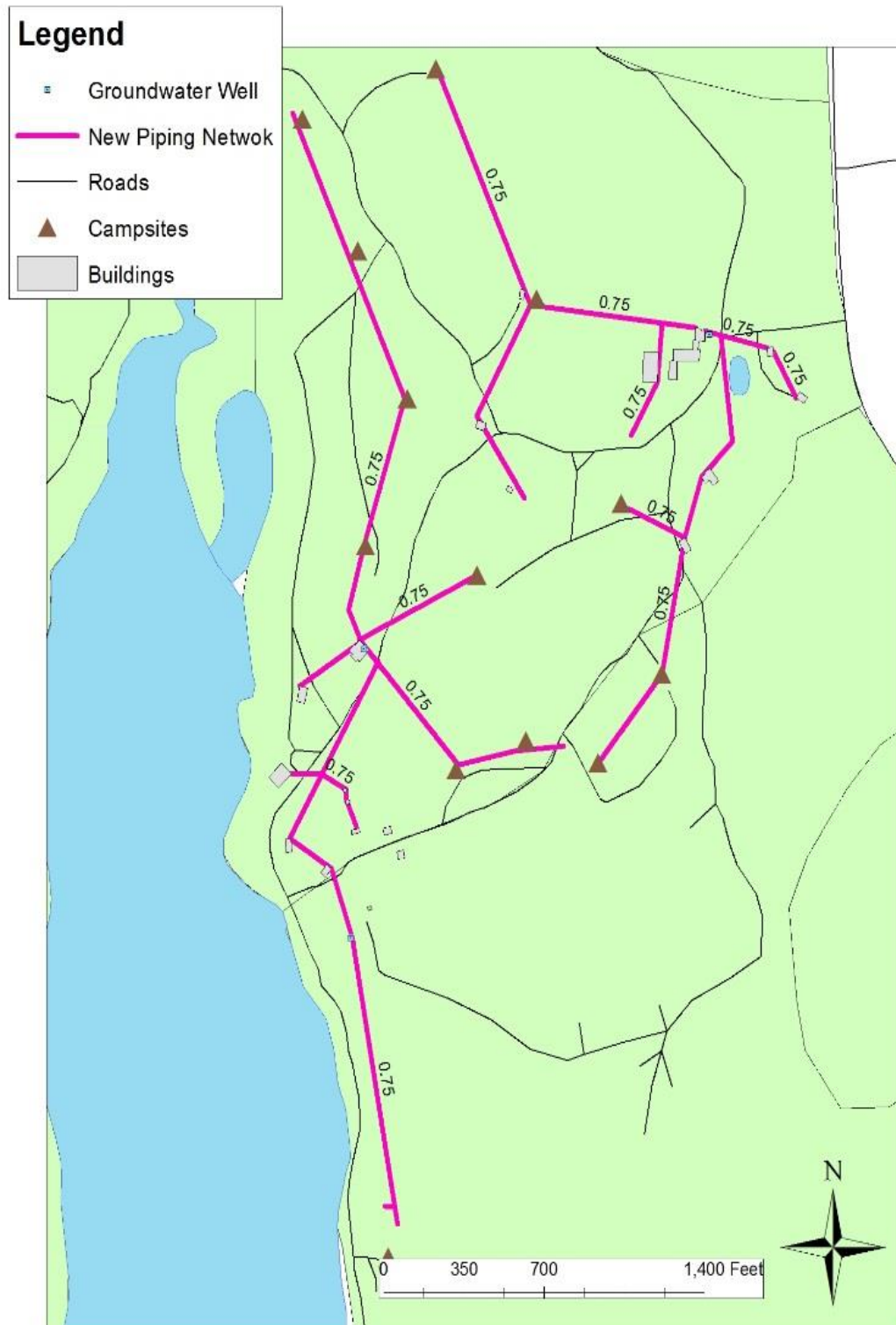


Figure 20: New pipe network of East Camp (Project Team, 2016)

5.4 Year-Round Water Distribution

One of the main goals of TVSR is to be able to supply potable water year-round to the reservation. To accomplish this goal, the team investigated the potential to winterize the current system. TVSR desires the use of their facilities in the winter months. The two methods to accomplish this recommendation investigated by the project team were including insulation and burying the pipe network. This is recommended for the entire water distribution system of TVSR, as it would improve the year round capabilities of the system.

When comparing the two methods of winterizing the pipe system, the costs of using insulation includes both the material and installation cost, whereas to winterize the pipes by trenching was only a labor cost. Associated costs with insulation and trenching are approximately \$50,000 and \$48,000 respectively. When different insulating materials were compared, rubber and foam insulation were found to be the most cost efficient materials, but foam was not as durable as rubber. By using insulation on the pipes, the pipes still retain the flexibility of being moved as demands at TVSR shift, but are also susceptible to physical damage. The process of trenching and burying the pipes makes the position permanent, however, it provides system stability and reduces the risk of damage. After considering all the factors involved in winterizing the system, the project team determined trenching the pipe network would be the best solution. When including all of the costs involved in the process, trenching was the cheapest alternative. The costs and time of installation to bury the above-ground water networks was estimated at \$48,000 for the whole system.

5.5 Maintain Current Well Locations

In the event that drilling new wells is not viable for the Reservation, then a “do nothing” scenario was considered. Within this scenario, contamination risks must still be addressed to maintain operational wells.

If the cost and labor associated with relocating either the Farmhouse or East Lodge Wells is too arduous for TVSR to consider, then there are other options which may be more feasible. Among these options are the relocation of septic fields and the relocation of East Lodge.

5.5.1 Relocate Septic Fields

To prevent future contamination of groundwater sources, another alternative would be to move or shut down septic or leaching fields within close proximity to well sites. Farmhouse and East Well would benefit from this proposal, as there are noted waste disposal fields close to the physical wells in each location, (recall Figure 15 and Figure 16). While this would be cumbersome and expensive, it is suggested in order to maintain the safety and operational longevity of TVSR’s water supply system. This option should be considered if the relocation of pumping wells is deemed too expensive or complex for TVSR to consider.

5.5.2 Relocate East Lodge

TVSR considers the age and current capabilities of the existing East Lodge as less than ideal for TVSR’s future, so a viable option would be the construction of a new building in a separate location. In its current location, the East Lodge Well does not meet modern building codes and is allowable only under an existing buildings clause in CMR 780. Modifications to the well location would trigger modern regulations on the existing structure. It may be reasonable to relocate the entire building rather than meet strict codes. This would eliminate the need to update the entire building to match modern day building code. The existing building or well could be

taken out of the water system and relocated. The project team understands that the cost of drilling a new well on top of the cost of a new structure would be exorbitant, so it would also be an option to establish a smaller structure to house the hydro-pneumatic tanks and well controls near the existing well location.

6.0 Conclusion and Recommendations

Long term goals for TVSR in the next 30 years focus on financial stability, continuous maintenance and improvement programs, as well as a dependable water system that is preserved for future generations. There is a desire to develop TVSR into a “premier camp in Central New England” (Warren quote), and it is the hope of the project team that this project will further that goal.

Ultimately, TVSR must be equipped to handle the current and future water demands on the reservation. With this in mind, the project team determined what components of a water distribution system TVSR already possessed and identified areas for improvement and expansion. New portions of the water system may be an unavoidable cost to TVSR, as enforcement of 2009 DEP regulations has brought the condition of existing wells at TVSR into question. With a strengthened and improved water distribution system the chance of catastrophic failure of a well or water source will be reduced for the foreseeable future. These improvements to the system rely on accurate water demand projections in order to model current and future growth of TVSR.

The culmination of this report resulted in the creation of Table 22, which details the ten potential modifications and recommendations to the water distribution system of TVSR. These modifications were ranked based on cost, constructability, and pertinence. These rankings were determined based on cost and time estimates generated by the project team, coupled with the desirability of each modification based on stakeholder input. Each potential modification was given a numeric ranking that differentiates the feasibility of the options. The methodology behind these rankings is detailed in Section 3.3 of this report.

Table 22: Design rubric for modifications to TVSR's water distribution system				
	Cost	Constructability	Desirability	Feasibility
Well contamination treatment (5.1)	1	1	1	3
Well relocation (5.2)	1	2	1	4
Implementation of storage tanks (5.5)	1	1	3	5
Replacing existing pipe (5.3)	2	3	2	7
Water system expansion (5.3)	2	2	2	6
Winterizing pipe system (5.4)	3	3	2	8
Fire suppression system	4	3	2	9
Moving septic fields (5.5.1)	4	3	3	10
Relocation of East Lodge (5.5.2)	4	4	3	11
Ranges for cost (\$\$): 1: 0-15,000 2: 15,000-25,000 3: 25,000-50,000 4: 50,000+				
Constructability (time): 1: 1-2 weeks 2: 1-2 months 3: 3-6 months 4: 6+months				
Desirability: 1: desirable 2: moderately desirable 3: least desirable				

According to the project team's cost analysis of these modifications, several prices rankings were established in Table 22. The time attributed to system enhancements were rated similarly to cost, as to express the equal importance of each for the proposed modifications. These objective categories were weighted higher than the subjective category of desirability. This was done to show that time and cost of proposed alterations should have a greater role in the feasibility of modification implementation than subjective desirability of the project team and TVSR stakeholders.

The final result of this design rubric shows the proposed modifications to the water system of TVSR ranked by feasibility. The modifications that were ranked highest were contamination treatment, well relocation, storage tanks implementation, and water system expansion.

Well contamination treatment was the least expensive, quickest to implement, while also being the most highly valued modification by TVSR stakeholders. The highest importance of this option was shared by the project team and the stakeholders of TVSR. Well relocation was the second most feasible category and was only hindered by the time of implementation, as the construction process was determined to take approximately one to two months. While storage tank implementation entailed low costs and short installation times, the desirability of this option by the stakeholders was lower than that of the two aforementioned modifications. The expansion of the drinking water system, which would increase the capacity of TVSR to accommodate more campers was determined to be valued by the stakeholders, but was limited by the cost and time commitment unlike the higher ranked modifications.

In theory, TVSR could choose to do nothing to the water distribution system, but this is not a recommended course of action. In its given state, TVSR's water distribution system could suffer from aging infrastructure and regulatory infractions in the future, which could lead to the closure of the reservation. Addressing existing concerns of the water distribution system and engaging in robust preventive maintenance will undoubtedly save TVSR time and money and allow for the reservation to potentially expand operational capabilities.

While all of these modifications would help TVSR, the project team chose to recommend the following alternatives: water contamination treatment, well relocation, storage tank installation, and water system expansion. Treating the contamination risks of various wells would between \$4,000-14,000. Relocating a well in TVSR would cost between \$5,000-6,500. The costs

associated with installing storage tanks is estimated at less than \$5,000, and the overall expansion of the water distribution system could cost between \$4,000 and \$50,000. These alternatives were chosen because of their low cost and their time and ease of implementation. These projects have the potential to improve and enhance TVSR's water distribution system and provide the reservation with enough short term flexibility to consider long term projects such as the relocation of East Lodge.

7.0 Recommendations for Future Studies

The project team recommends the following five areas for further study at TVSR. The order in which these recommendations appear are the suggested order of study:

West Camp revitalization and expansion

The expansive nature of the downed water system in the West Camp portion of TVSR establishes the basis of an entirely new potential study for future students. It would be beneficial for future camp expansion to revitalize this portion of TVSR by first establishing a reliable water supply system. The existing West Camp well does not have the capacity to support this growth and the Boonesville Well source is not in operation, so planning and testing would be necessary in order to determine the most efficient method of water sourcing. Many of the campsites in the West Camp are not suitable for inhabitation for any duration and do not have water amenities, so if a future team were to design an example campsite with water access, this would benefit TVSR.

Water Quality

The project team was made aware of issues pertaining to TVSR's quality of some of their drinking water. Contaminants have been reported in the water such as coliform bacteria, iron, and manganese, as recently as 2014 by TVSR. Future studies into determining the status of the drinking water should be conducted. An in depth analysis should also be done to determine possible sources of contamination and recommend fixes to these problems. Such sources of contamination could be a result of the location of the wells to septic fields and the use of chlorine stripping old steel pipes. Another aspect of this project could address the effectiveness of the chlorine drip system on the Farmhouse Well and tracking the residual chlorine through the distribution system.

East Lodge Relocation/Remodel

The relocation and remodeling of East Lodge would provide TVSR with the ability to serve more campers during peak usage. Relocation is advised over remodeling, only if the regulatory

issues associated with the East Lodge well have not been resolved. TVSR intends to expand the dining capacity of East Lodge, but are restricted by current building and well regulations. This would be an important area for TVSR to conduct further studies as the East Lodge is the most important building of the Reservation, since it serves as the epicenter of camper activity during the summer sessions.

Septic Study

A study of the septic systems and waste management services of TVSR is suggested by the project team. The potential replacement of many individual systems by the installation of a small sewage treatment plant on TVSR property may prove beneficial for future growth. By centralizing waste management at TVSR, the reservation would gain treatment capacity to expand the total number of campers TVSR could handle at peak capacity.

Rethinking how waste is handled at TVSR could also free up areas for future groundwater wells and other activities restricted by the presence of septic fields. Granted, these areas would not be immediately available after the removal of a septic field, but these spaces could be available in the future.

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